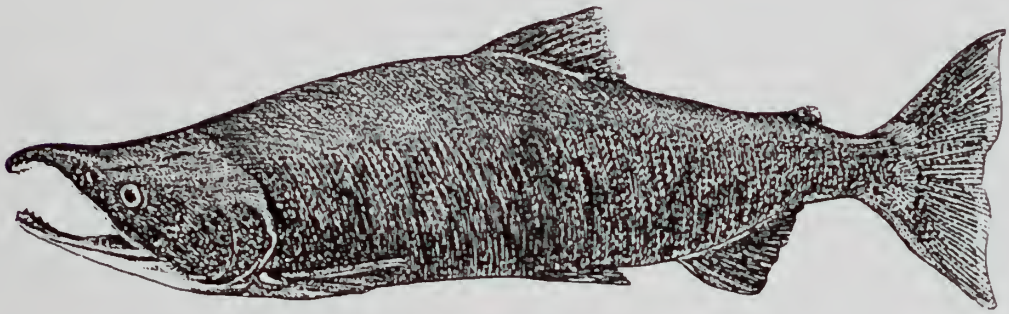
Status Report on the Water Quality of Lake Ozette and Potential Human-related Impacts on Salmonids



November 2001

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TABLE OF CONTENTS

LIST OF FIGURES, TABLES, AND APPENDICES

11. Concentrations of nutrients in water samples collected from Lake Ozette, July 18, 1994. Samples collected from the surface, 18 m, and near the bottom in mg/L. Dissolved PO_4-P values equal to 0.001 were below the
12.
13. detection level of the lab instruments.
14. Chemical composition in mg/L of water samples collected from Lake Ozette Stations 1 – 4 on August 29 – 30, 1993.
15. Chemical composition in mg/L of water samples collected from Lake Ozette stations 1 – 4 on January 18 1994.
16. Chemical composition in mg/L of water samples collected from Lake Ozette Stations 1 – 4 on May 23, 1994.
17. Chemical composition in mg/L of water samples collected from Lake Ozette Stations 1 – 4 on July 18, 1994.
18. Concentrations of chlorophyll at 0-20 m collected from Lake Ozette sampling Stations 1,2, and 4, 1994.
19. Mean monthly densities (number/m^3) of zooplankton taxa in 0-30 and 0-5 m vertical tows, Lake Ozette, 1994.
20. Plant taxa identified in vegetation plots at Lake Ozette.
21. Range of values for water quality variables collected in the tributaries and outlet to Lake Ozette, 1993-94. Only includes data collected between December 1993 - November 1994 with the Hydrolab multi-parameter probe. Discharges are not representative of peak flows as it was not possible to wade these streams at high flows, especially in Crooked Creek and Big and Ozette Rivers.
22. Monthly water quality values for the **Ozette River**, 1993-94. Data collected on January 5, 1994 and prior to December 15, 1993 measured with various hand held instruments; all other information measured with a Hydrolab multi-parameter instrument. Measurements made on December 11, 1993, March 2, and November 30, 1994 collected during storm events.
23. Monthly water quality values for **Coal Creek**, 1993-94. All data collected with a Hydrolab multi-parameter instrument. Measurements made on March 2 and November 30, 1994 collected during storm events.
24. Monthly water quality values for **Umbrella Creek**, 1993-94. Data collected on January 5, 1994 and prior to December 15, 1993 measured with various hand held instruments; all other information measured with a Hydrolab multi-parameter instrument. Measurements made on December 11, 1993, March 2, and November 30, 1994 collected during storm events.
25. Water quality values for **Big River**, 1993-94. Data collected on January 5, 1994 and prior to December 15, 1993 measured with hand held instruments; all other information measured with a Hydrolab multi-parameter instrument. Measurements made on December 11, 1993, March 2, and November 30, 1994 collected during storm events.
26. Monthly water quality values for **Crooked Creek**, 1993-94. Data collected on January 5, 1994 and prior to December 15, 1993 measured with various hand held instruments; all other information measured with a Hydrolab multi-parameter instrument. Measurements made on December 11, 1993, March 2, and November 30, 1994 collected during storm events.
27. Monthly water quality values for **Siwash Creek**, 1993-94 Data collected on January 5, 1994 and prior to December 15, 1993 measured with various hand held instruments; all other information measured with a Hydrolab multi-parameter instrument. Measurements made on December 11, 1993 and March 2, 1994 collected during storm events.
28. Monthly water quality values for **South Creek**, 1993-94. Data collected on January 5, 1994 and prior to December 15, 1993 measured with various hand held instruments; all other information measured with a Hydrolab multi-parameter instrument. Measurements made on March 2, 1994 collected during a storm event.
29. Fish captured by electrofishing in four reaches of Siwash Creek, July 25, 1994.
30. Fish captured by electrofishing in four reaches of Big River, July 26, 1994. Reach 1 is the farthest downstream.
31. Annual total precipitation, minimum, maximum, range, and mean monthly lake levels recorded at the Lake Ozette Ranger Station, 1981-94 and 1998-99.
32. Stand age, road density and road crossings in the Ozette watershed.

Appendices

Appendix A: Calibration Procedures for the Hydrolab Datasonde 3.
Appendix B: Lake Ozette Vegetation Transect and Plot Descriptions.
Appendix C: Lake Ozette Vegetation Plot Results.
Appendix D: Temperature Data from Lake Ozette Tributaries.

ABSTRACT

Physical, biological, and chemical characteristics of Lake Ozette and water quality in six tributaries to the lake were described from September 1993 to October 1994. The annual range of water quality conditions were measured for water temperature, specific conductance, turbidity, and pH at four locations on the lake, six tributary streams, and at the lake outlet. Water quality conditions in the lake generally appeared to be favorable to salmonids although condition were less favorable in tributary streams. The lake exhibited thermal stratification throughout the summer months and circulated freely from December to March at water temperatures of less than 9°C. Dissolved oxygen in the lake ranged from 8.6 to 12.4 mg/L throughout the year, and pH values (ranged from 6.7 to 7.7) were consistent with those observed in other lakes. Specific conductivity was relatively low and uniform throughout the water column (ranged from 33.7 to 43.2 uS/cm). Turbidity varied greatly by sample station, date, and depth. During routine sampling, surface waters exhibited turbidity levels from 1.4 to 18.0 NTU's but elevated turbidity as high as 35 NTU's occurred after a storm event. From December 1993 to October 1994, mean secchi disk readings ranged from 3.7 to 6.5 m in depth. There were no consistent changes in concentration of Kjeldhal-N, total dissolved phosphorus, orthophosphate-P, and ammonia-N with increased depth during the sampling period. The zooplankton community was comprised of nine crustacean and 15 rotifer taxa. Density of cladoceran taxa was generally highest in May and July, and rotifer taxa that were present throughout the sampling season were at maximum densities in July based on vertical net tows. Chlorophyll varied with water depth and time, and results clearly indicate that most chlorophyll was located in the upper portion of the water column in the lake. Water chemistry, nutrients, and zooplankton densities were within the ranges reported for other lakes with sockeye in Washington, Alaska, and British Columbia. A cursory inventory of lakeshore vegetation identified 24 plant taxa in transects distributed around the perimeter of Lake Ozette. Water quality conditions in tributaries to Lake Ozette exceeded Washington State maximum temperature standards for Class AA waters (16.3^{0}C as required by the Forest Practices Act) in four of the lake's tributaries. Maximum daily water temperatures in the Ozette River exceeded the preferred temperature range (7.2 to 15.6^{0}C) for migratory adult sockeye salmon in July and August. Elevated turbidity levels were observed in Big River (185 NTU) and Umbrella Creek (161 NTU) during storm events. Poor water quality conditions in tributaries to the lake's eastern shoreline are believed to have contributed to the decline of sockeye salmon in the Ozette basin. Degraded water quality in these streams appears to have resulted from extensive timber harvest in the watershed, which began early in this century and accelerated in the 1970's.

INTRODUCTION

Lake Ozette is a 2,954 ha coastal lake located in the northwest corner of Washington State (Figure 1). The lake lies entirely within Olympic National Park (ONP) although most of the watershed is located on private forest lands. The lake and its tributaries support anadromous and resident populations of fish but returns of Pacific salmon to the Lake Ozette basin have declined since the 1950's (WDFW et al. 1993). The decline of Ozette salmon, and especially sockeye, have led to several assessments of adult returns, juvenile production and habitat conditions within the watershed. In 1976-77, Bortleson and Dion (1979) investigated the water quality of the lake and its tributaries relative to their ability to support salmonids. While they found generally suitable habitat conditions, their assessment occurred prior to the period of peak timber harvest in the basin. Timber harvest and road building activities that have occurred since Bortleson and Dion's (1979) study may have resulted in negative impacts on water quality conditions. These impacts have likely influenced productivity of salmon.

In addition to the decline of the lake's fish populations, Olympic National Park staff was concerned about alterations to natural processes in the watershed including the invasion of non-native plants, changes in the water quality of the lake and its tributaries, and a suspected increase in sediment transport from the tributaries to the lake. In the mid-1980's, park staff frequently noted high turbidity levels in the lake's tributaries and along the eastern shoreline during period of heavy rain fall. Turbidity levels were reported to be high during these periods of high rainfall and were often associated with log truck hauling on the extensive network of gravel roads in the basin outside of the park.

The United States Congress acknowledged the existence of threats to the health of the Lake Ozette ecosystem in the Washington Parks Wilderness Act of 1988. Congress directed the National Park Service to "conduct a study of the watershed of Lake Ozette" and "consider the various alternatives to protect this area." This study responds to the congressional directive by documenting water quality conditions in the watershed and assessing potential impacts to fish resources. Specifically, the objectives of this study were to: 1) determine water quality conditions in Lake Ozette and its tributaries; 2) provide baseline data for future water quality studies that occur in the basin; and 3) identify potential factors in the decline of salmonids in the Ozette basin.

STUDY AREA

Lake Ozette is the largest lake in Olympic National Park and the third largest natural lake in the State of Washington. While the lake is relatively large, its drainage basin is small at 199 km^2. Lake Ozette lies approximately 9 m above sea level, has a maximum depth of 98 m (Figure 2), and the highest elevation in the drainage is 580 m. The Ozette River

flows north into the Pacific Ocean from the northern end of the lake. Due to the lake's close proximity to the ocean, it maintains a cool maritime climate and receives over 250 cm of precipitation per year, mainly in the form of rain.

The Lake Ozette basin contains forests of Sitka spruce (*Picea sitchensis*), western hemlock (*Tsuga heterophylla*), western red cedar (*Thuja plicata*), Douglas-fir (*Pseudotsuga menziesii*), and red alder (*Alnus rubra*). A high portion of the watershed is in the early stages of second growth and little old-growth forest remains outside ONP. The strip of park-owned land along the south and east shores of the lake is quite narrow, and likely does not buffer the lake from land-use activities in the basin.

European settlement began in the Lake Ozette drainage during the mid-1800's and by 1892, 33 families occupied the area. Evans (1983) reported that they grew crops, raised livestock, and seasonally logged the land. In 1926, the first road was extended into Swan Bay from Clallam Bay and active logging began in the 1930's (Bortleson and Dion 1979). In 1953, the area west of the lake was added to ONP and in 1976, the lake itself and a strip of land along the east shore were included within the park boundaries. Extensive clear-cut logging occurred in the 1950's and accelerated by 1970 (Buck Adamire, logging foremen in the Ozette basin, personnel communication).

The Lake Ozette basin supports 19 anadromous and resident fish species (Table1). Historic catch records (Table 2) indicate that the lake once supported relatively abundant populations of sockeye salmon (*Oncorhynchus nerka*), chinook salmon (*O. tshawytscha*), chum salmon (*O. keta*), and coho salmon (*O. kisutch*). Although there are no available estimates of annual fishing effort, Makah Tribal catches suggest that the abundance of each of these species began to decline in the 1950's. From 1977 to 1995, terminal run sizes of adult sockeye ranged form 263 to 2,191 based on data collected by the US Fish and Wildlife Service (FWS) and Makah Tribe (Dlugokenski et al. 1981, LaRiviere 1991, and LaRiviere 1992). These numbers suggest that sockeye are much less abundant when compared to the 1950's when annual catches were as high as 17,000 fish. Nehlsen et al. (1991) concluded that coho, chum, and chinook salmon in Lake Ozette are of special concern or face a high risk of extirpation.

In 1996, a panel of fishery experts was assembled by the Biological Resources Division of the United States Geological Service to review available information related to Lake Ozette sockeye salmon (Jacobs et al. 1996). Based on data presented in this report and other sources, the panel concluded that the decline in abundance of sockeye was probably related to numerous factors including over-fishing, predation by native and non-native fish and wildlife, and habitat degradation in tributaries and along the lake shoreline. The panel suspected that the recent declines in spawning escapement would result in a listing of Lake Ozette sockeye under the Endangered Species Act. A subsequent review of the status of sockeye populations in Washington and Oregon by the National Marine Fisheries Service (Gustafson et al. 1997) resulted in the listing of Ozette sockeye as a "threatened" species in March, 1999.

METHODS

Emphasis in this study was placed on the water quality of Lake Ozette, six tributaries to the lake, and the lake outlet. In addition to measurements of water quality variables, we collected information on zooplankton assemblages, chlorophyll concentration, fish species composition in Big River and Siwash Creek, and lakeshore vegetation. Water quality sampling in Lake Ozette occurred at four sampling stations (Figure 3) located in close proximity to sites that were sampled by the US Geological Survey in 1976-77 (Bortleson and Dion 1979). These sample stations were distributed along a north-south axis, and are believed to be representative of the range of conditions in the lake. Depths ranged from 27 meters (m) at Station 1 in the North Arm to more than 74 m at Station 4 which was beyond the limits of our sampling equipment. To insure that sampling occurred at the same location on each date, buoys were anchored at each of the four stations.

Water quality sampling sites also were located in tributaries to the lake including Big River, Umbrella, Crooked, Siwash, and South Creeks (Figure 3). The sample sites on Crooked, Siwash, and South Creeks were located near the park boundary immediately upstream from the lake. Sampling on Big River and Umbrella Creek occurred upstream of the park boundary at the East Swan Bay and Hoko-Ozette bridges, respectively. These sites were located farther upstream in areas that were wadeable during most stream flows. Periodic sampling also occurred in the Ozette River near the lake outlet and in Coal Creek (a tributary to the Ozette River) which is located immediately downstream from the foot bridge at the Ozette Ranger Station.

Water Quality Monitoring: From September to November 1993, water samples were collected at the four sampling stations in the lake using a manually operated downrigger and hand-held water quality instruments. A multiparameter water quality probe (Hydrolab Datasonde 3) was used for all data collection that occurred in the lake and tributaries from December 1993 to August 1994. The Hydrolab was used to obtain monthly recordings of water temperature (C), specific conductance (μS/cm), pH, reduction-oxidation potential or redox (mv), dissolved oxygen (mg/L), and turbidity (NTU). As a result of inconsistent turbidity readings, the turbidity sensor was replaced and on May 23, 1994 and a Hydrolab H20 was used for sampling.

Care was taken in calibrating the Hydrolab prior to its use in the field and weekly maintenance of the unit was necessary. The Hydrolab was routinely calibrated within 24 hours of field sampling by immersing the sensors in standardized solutions for each water quality variable. Engineers at the Hydrolab Corporation recommended specific standards based on values obtained from previous sampling at Lake Ozette. At each of the four lake stations, the unit was lowered at 1.5 – 3.0 m intervals until it reached the lake bottom or the cable was fully extended (74 m). All data were stored in a Surveyor 3 data logger, and later downloaded into a spreadsheet. Specific details regarding calibration of each variable were recorded (Appendix A).

Transparency, or water clarity, was determined at various lake stations by using a 20 cm diameter black and white Secchi disk. The Secchi disk was lowered over the side of the boat at each lake station and the point that it disappeared and reappeared was recorded. The procedure was normally repeated twice and readings were recorded as the mean of the ascending and descending values. Whenever possible, measurements were taken during calm periods with little wave action between 1000 and 1630 hours.

Monthly stream discharge (cfs) values were determined in the Ozette River, Big River, Coal Creek, Crooked Creek, Siwash Creek, South Creek, and Umbrella Creek from the July 1993 to November 1994 (except no discharges were collected during periods of extremely high flows). River discharge was measured using a Marsh-McBirney flow meter.

To determine daily mean, minimum, and maximum water temperatures during the summer, Ryan TempMentors were deployed near the park boundary in South, Siwash, Crooked, and Umbrella Creeks from June 15 to October 26, 1994. Additionally, temperature loggers were placed in Big River and Ozette River at the East Swan Bay Bridge and Ozette Ranger Station, respectively. Each instrument was calibrated at the factory prior to their deployment, placed in a protective case, and secured along the stream bank.

Water Chemistry and Nutrients: To determine relative levels of nutrients and chemical constituents in Lake Ozette, water samples were collected on August 29 - 30, 1993, January 18, May 23, and July 18, 1994. Water samples were collected at Station 1 from depths of 1, 18, and 22 m, at Station 2 from depths of 1, 18, and 53 m, at Station 3 from depths of 1, 18, and 64 m, and at Station 4 from depths of 1, 18, and 62 m. All samples were collected using a downrigger with a four liter Van Dorn bottle lowered to the appropriate depth. At each depth, two liters were filtered and three liters were unfiltered. A Nalgene filter apparatus with 0.45 mm filter paper was used for all filtered samples. In addition, 40 mL of water was filtered into a 125 mL bottle, and three drops of nitric acid (HNO_3) were added. A total of 60 one-liter bottles (24 filtered and 36 unfiltered) and twelve 125 ml bottles were collected on each sample date. Prior to obtaining water from each depth, the entire filter apparatus was rinsed with distilled water and new filter paper was put in place. Sample bottles and filter papers were obtained from Cameron Jones, U. S. Forest Service, Cooperative Chemical Analytic Laboratory (CCAL). All samples were kept on ice in large coolers and next-day mailed to the CCAL in Corvallis, Oregon where they were analyzed for calcium, magnesium, potassium, sodium, sulfur, phosphorus, silica, iron, manganese, zinc, aluminum, boron, copper, cadmium, chromium, nickel, arsenic, antimony, lead, molybdenum, titanium, tin, strontium, ammonia nitrogen, dissolved sodium, potassium, calcium, magnesium, dissolved solids, suspended sediment, total Kjeldahl nitrogen, dissolved total phosphorus, dissolved phosphate phosphorus, nitrate-N and nitrite-N.

Chlorophyll: Water samples for chlorophyll a analysis were collected on May 24 and July 19, 1994 at Station 1 from depths of 1, 2, 5, 10, and 20 m, at Station 2 from depths of 1, 2, 5, 10, 20, 40, and 47 m, and at Station 4 from depths of

1, 2, 5, 10, 20, 40, and 60 m. Sample collection, storage, and analysis was conducted according to the procedures described by Larson et al. (1996). All chlorophyll samples were collected in a four liter Van Dorn bottle using a manual downrigger lowered to the appropriate depth. After water samples were collected from the lake, they were transferred from the Van Dorn to one liter opaque polyethylene bottles and stored in coolers with ice. Within two to five hours of collection, each bottle was inverted three times, and 500 mL of sample water were filtered using a 0.45 um Millipore filter placed on a clean Nalgene filtering apparatus. Before filtering the next sample, the top portion of the filter apparatus was thoroughly rinsed using deionized water (tap water on July 19). Filtration pressure was kept between 5 - 9 psi to reduce the chance of rupturing algal cells. With 40 mL of lake water remaining in the top of the filter, five drops of magnesium carbonate ($MgCO_3$) were added to each sample. After filtration, each filter paper was individually folded in quarters with tripled-rinsed tweezers, transferred to pre-labeled scintillation vials wrapped in tin foil and the volume filtered was noted. All vials were placed in Zip-loc bags and immediately stored in a freezer.

The entire filtration process was conducted at the Lake Ozette Ranger Station in a dark room to prevent degradation of chlorophyll samples. One chlorophyll "blank" for each sample date was created by filtering 40 mL of deionized water and adding 5 drops of $MgCO_3$. All samples were shipped to the USGS, Forest and Rangeland Ecosystem Science Center at Oregon State University for analysis (McIntire et al. 1996).

Zooplankton: Zooplankton samples were collected during day light hours on February 22, May 24, and July 19, 1994 at lake Stations 1, 2, and 4. Vertical tows were hauled from 30, 20, 10 and 5 m to the surface using a 64 micrometer mesh net with an opening of 0.2 m and no closing apparatus (the deepest tow on July 19 was from 25 m to surface). Replicate tows were collected at each station and at each depth.

Vertical tows for zooplankton typically were taken during calm periods on the lake. With the zooplankton net held vertically, it was lowered to the desired depth and slowly retrieved at a rate of 0.5 m/s. Prior to removing the cup containing the sample, all sides of the net were rinsed with water and/or 95% ethanol forcing any attached organisms to the bottom of the net. All contents were then emptied into a 250 mL wide-mouth polypropylene bottle with a polyvinyl liner. To preserve each sample, one-eighth of a tablet of Alka-Seltzer was added to 95% ethanol. The Alka-Seltzer allowed for better preservation of active organisms such as rotifers and was allowed to completely dissolve before any alcohol was added. The net was thoroughly rinsed with distilled water before lowering it to the next depth. Zooplankton samples were stored in the dark, and later delivered to the Forest and Rangeland Ecosystem Science Center at Oregon State University where they were identified and enumerated (Larson et al. 1996). Zooplankton densities were averaged throughout the three sampling stations for each month and depth. Data were presented for the 5 m and 30 m vertical net tows.

Fish Observations and Sampling: ONP divers conducted SCUBA surveys along Baby Island, Olsen's Beach, and

north of Allen's Slough on December 16, 1994. The divers recorded the number of adult sockeye in the area, depth of redds, and composition of substrate at each redd.

On August 24, 1994, a visual survey of the substrate along the entire lakeshore was conducted during a period when the lake was at its seasonal low and much of the beach was exposed. This survey was conducted by boat with an observer standing on the bow as it slowly cruised along the shoreline of the lake. The boat traveled parallel to the shoreline at a distance that allowed clear observation of the bottom which was visible to depths of approximately 3 m. The predominant substrate type was categorized as silt, sand, gravel, cobble, and boulder.

Backpack electrofishing surveys were conducted to determine fish species composition and distribution at four sites in Siwash Creek and Big River on July 25 and 26, 1994. A Smith-Root battery operated electroshocker with settings of 60 Hz and 500 volts was used in both streams. One pass electrofishing without block-nets was conducted and relative effort was recorded at each site (e.g. time spent electrofishing). The four sites were distributed throughout portions of the drainage believed to be accessible to anadromous fish. The sites on Big River were located at river km 1.2, 5.6, 7.2, and 10.5 and 0.2, 0.5, 2.4, and 3.2 on Siwash Creek. These two streams were selected based on good access. Sampling generally proceeded upstream from the access point and continued through representative habitats for 20 – 45 minutes of electrofishing time.

Vegetation Monitoring: To provide a baseline for monitoring gross changes in shoreline vegetation and to assess potential encroachment of vegetation into the lake, plots were established within the riparian zone of Lake Ozette along seven transects (Figure 3). The seven transects (A - G) were distributed around the lake and were believed to be representative of various vegetation and substrate types. Transects C, E, G, and F were established along the lake shore and within 100 m of the mouths of South, Crooked, and Umbrella Creeks and Big River, respectively. Sand, silt, or mud dominated the substrate in these four areas. Transects B and D were located along the shore near Cemetery Point and just north of Siwash Creek, respectively. These two areas are utilized by sockeye for spawning. Transect A was located on the northwest shore near the Ozette Ranger Station immediately south of the outlet.

A two meter, steel fence post was driven into the ground at each site near the forest/shrub boundary, and a one meter section of rebar was driven into the ground approximately two meters from the fence post on a line perpendicular to the lake shore. A compass bearing was taken along each fence post toward the lakeshore to establish a transect line. Vegetation plots were laid out in rectangular 10 m^2 quadrates (2 m by 5 m), oriented parallel to one another, and bisected by the transect line. The plots were placed in areas of homogenous vegetation and in areas of "transition" where one dominant species graded into a different type of vegetation. Where aquatic vegetation occurred at the edge of the lake, the plot extended beyond the shoreline into the lake to the outer edge of the vegetation. Distances were recorded from the fence post to the leading edge of each plot, the lake shore, and to the outer edge of the aquatic

vegetation. The percent cover of dominant, co-dominant, and less abundant vegetation was visually assessed within each plot.

RESULTS

Lake Ozette

Water Temperature and Dissolved Oxygen: From December 1993 to late February 1994, water temperatures remained relatively constant (7.04 - 8.64° C) from the surface to the bottom of the lake (or the lower limit of the Hydrolab's cable) and circulation occurred to a depth of at least 65 m (Figure 4). In late April, surface waters began to warm and thermal resistance to mixing began to breakdown. Complete thermal stratification was evident by June with nearly uniform temperatures from the surface to a depth of 9 m in the upper stratum. Based on mean water temperature data from June to September, the metalimnion occurred from 9 to 21 m (Figure 4). A distinct pattern of thermal stratification was evident in August 1994 when the epilimnion extended down to approximately 8 m (at Station 4), a fully developed thermocline was present from about 9 to 17 m, and a well formed hypolimnion below that depth.

From the surface to 6 m, the lake was warm in late summer with a maximum temperature of 21.04° C recorded in August 1994 (Tables 3-6). Surface temperatures remained warm throughout September and significant cooling began to occur in October (Figure 5). There was an increase in temperature at 15 m in October, and relatively uniform temperatures from 24 - 67 m throughout the entire year. The lake remained stratified with an epilimnion that extended to approximately 16 m as late as October 18. Cooling of surface waters eventually caused a lowering of the thermocline. Following summer stratification, surface temperatures gradually decreased until the onset of lake circulation.

Dissolved oxygen concentrations in the surface waters of Lake Ozette remained near saturation and ranged from 8.61 - 12.38 mg/L (Tables 3-6). Throughout the entire year and at all depths, dissolved oxygen concentrations were greater than 8.06 mg/L (Figure 5). During months of complete circulation from December to February, dissolved oxygen was nearly uniform throughout the water column. The highest reading of 12.38 mg/L was recorded at the surface in April, with 11.23 mg/L recorded at a depth of 70 m on the same date. The lowest dissolved oxygen concentrations were consistently found in the metalimnion in August, September, and October of 1994.

pH: Near-surface pH values of Lake Ozette ranged from 6.70 - 7.74 for all lake stations (Tables 3-6). The pH at all lake stations tended to gradually decrease with depth throughout the entire year (Figure 6). Surface waters yielded a high value of 7.90, the lowest pH value of 6.11 occurred at 72 m. During thermal stratification in August, pH declined

with increased depth in the epilimnion and metalimnion at Station 4.

Specific Conductance: Conductivity in the surface waters of Lake Ozette ranged from 33.70 - 43.20 uS/cm and was uniform at all lake stations (Tables 3-6). During periods of circulation between December and March, conductivity readings remained relatively uniform throughout the entire water column (Figure 7). However, with the onset of thermal stratification in May 1994, specific conductance readings gradually declined with increased depth.

Turbidity: Turbidity readings in Lake Ozette fluctuated widely by station, date, and depth. After eliminating outlier values, which were attributed to malfunctions in the Hydrolab's sensor, turbidity readings in the near surface waters of the lake ranged from 1.4 to 18.0 NTU during routine monitoring (Tables 3-6). Relatively low values were measured throughout the year except during the months of May and June.

In addition to routine monitoring at the four sample sites, turbidity was assessed in March following a storm event. Heavy rains had fallen on March 1 and 2, 1994 (approximately 10 cm) raising the level of the lake and flooding the Ozette Campground. Tributaries to the lake were at flood stage and notably turbid. Discharge and turbidity levels had fallen by March 3 but were still fairly high when monitoring was conducted by boat at the mouths of the tributaries and various locations on the lake. A light rain was falling along with a relatively strong wind blowing from the southwest.

A plume of dark, brown water was evident in Swan Bay and turbidity in the center of the bay measured 35.1 NTU at the surface, 34.7 at 3 m, 27.3 at 6 m, 19.0 at 9 m and 13.8 at 13 m, which is at the bottom (Figure 8). Turbidity levels in the mouths of Big River and Crooked Creek, were 33.9 and 12.2 NTU, respectively. This plume of turbid water extended out of Swan Bay and into the main part of the lake where it was apparently being pushed by the southwesterly winds toward the north end of the lake. Just north of Jersted Point, it was joined by turbid water from Umbrella Creek. Turbidity in the mouth of Umbrella Creek measured 18.9 NTU. Turbidity readings in Umbrella Bay ranged from 13.9 NTU at the surface and 8.8 NTU at the bottom (12 m). Turbidity decreased as the plume was pushed into the north arm of the lake and measured between nine and 10 NTU from the surface to the bottom (27 m) at lake monitoring Station 1. Turbidity levels at the mouths of South and Siwash creeks were 13.0 and 10.2 NTU, respectively, and no plume of turbid water was observed in the south and central portions of the lake where background levels were eight NTU.

Secchi disk readings showed considerable variation from December 1993 to October 1994 (Table 7). Measurements ranged from 3.7 - 6.5 m at the four lake stations. This variation may, in part, be explained by weather conditions and/or differences in individual observer's ability to detect the disk.

No distinct water clarity trends were evident although August - October readings tended to be higher than other months.

The deepest reading (6.5 m) occurred on November 9, 1993 at Station 1, the shallowest of the four lake stations.

Water Chemistry and Nutrients: Kjeldahl-N, total dissolved phosphorus, orthophosphate-P, and ammonia-N did not demonstrate any consistent patterns in concentration with increased lake depth in August 1993, and from January to July 1994 (Tables 8-11). Concentrations of nitrate also did not show any changes with increased lake depth in January 1994, but the lowest concentrations occurred near the lake surface in May and July. On a seasonal basis, Kjeldahl-N was slightly higher in concentration in May as compared to concentrations observed in August, January, and July. Total dissolved phosphorus increased slightly from January to July, concentrations in August generally were intermediate between the concentration observed in May and July. Orthophosphorus-P was slightly higher in concentration in January 1994, relative to concentrations observed on other sampling dates. Nitrate increased slightly in the deep lake from January to July. Ammonia-N was highest in concentration in July at varying depths.

Based on concentrations of total nitrogen (Kjeldahl-N+nitrate), Lake Ozette can be classified as an oligotrophic to oligotrophic/mesotrophic lake (Wetzel 1983). The lake probably is phosphorus limited.

Chemical composition of water samples collected at each lake station are summarized in Tables 12-15.

Chlorophyll: Concentrations of chlorophyll at Stations 1, 2, and 4, ranged from 7.6 to 11.5 mg/m^2 and 0.4 to 0.6 mg/m^3 in April and May for samples collected between the lake surface and 20 m (Table 16). In July, chlorophyll concentrations at Stations 1 and 2 ranged from 11.9 to 13.7 mg/m^2 and 0.6 to 0.7 mg/m^3. For samples collected to a depth of 5 m, concentrations of chlorophyll ranged from 3.1 to 6.0 mg/m^2 and 0.6 to 1.2 mg/m^3 in April and May, and 6.3 to 6.6 mg/m^2 and 1.3 mg/m^3 in July. Based on the concentration of chlorophyll/m^2 to a depth of 5 m divided by the concentration/m^2 to a depth of 20 x 100, the former ranged form 30 - 71.6% of the latter in April and May, and 46.1 - 55.5% in July. Based on the concentrations of chlorophyll, Lake Ozette can be classified as an oligotrophic lake (Wetzel 1983). The ratio of concentrations/m^2 between samples collected to a depth of 5 m and samples collected to a depth of 20 m clearly showed that most of the chlorophyll in Lake Ozette is in the upper portion of the water column.

Zooplankton: Collectively, the zooplankton assemblage in Lake Ozette was comprised of nine crustacean taxa and 15 rotifer taxa (Table 17). There were 7 cladoceran taxa, one copepod taxa, and one cyclopedia taxa.

Based on the 30 m vertical net tows, most cladoceran taxa peaked in density in May (Table 17). *Sida crystallina* was an exception in that its density was highest in July. *Diaptomous oregonensis* was at maximum density in February, where as *Cyclops biscuspidatus* densities increased from February through July. Although some rotifer taxa only were present either in February or May, those rotifer taxa present throughout the sampling season were at maximum densities in July.

In the upper 5 m stratum of the lake, densities of crustacean taxa were higher than those in the 30 m tow (Table 17). Seasonal patterns of density were similar to those observed in the 30 m tow, except *D. oregonensis* density was highest in May and July and *C. biscuspidatus* was at maximum density in May.

The zooplankton community in Lake Ozette contains the species preferred by juvenile sockeye as prey and in numbers comparable to other sockeye producing lakes. Meehan and Bjornn (1991) identify *Daphnia* sp. as the preferred species followed by *Bosmina* sp., *Cyclops* sp., and other zooplankton species.

Observations of Lakeshore Sockeye Spawners: A total of seven sockeye redds were observed in water depths that ranged from 0.3 to 3 m (mean depth=1.3 m) on December 16, 1994 near Olsen's Beach, Baby Island, and Allen's Beach. These redds were constructed in sand and gravel that ranged from 15 to 20 cm in diameter. Most of these redds were located in less than one meter of water and several were constructed adjacent to clumps of emergent vegetation. Below three meters, the substrate is comprised primarily of sand with some gravel. Redds observed along the west shore at Allen's Beach were approximately the same size but appeared to be at slightly shallower depths and the substrate had a much higher percentage of larger gravel and cobble.

Based on our visual survey of the lake's littoral zone, much of the substrate along the lake's shoreline is composed of fine sediment (silt/organics) and/or sand, especially in Umbrella, Swan, and Ericsons bays. There are long stretches of gravel and cobble along the western shore from Rocky Point to Allen's Slough. Despite what appear to be long stretches of suitable substrate along the western shore, only the area north of Allen's Slough is known to consistently support sockeye spawning (subsequent dive surveys by the Makah Tribe has documented additional beach spawning areas used by sockeye; personnel communication, Mike Haggerty). There were scattered patches of gravel along the eastern shore in shallow water with sand immediately below. The most consistently used sockeye spawning site at Olsen's Beach was composed of a narrow strip of gravel which changes into sand at depths greater than about three meters.

Vegetation Monitoring: A total of 24 plant taxa were identified in the vegetation transects along the lake shore. Plant genera or species identified in vegetation plots at Lake Ozette are listed in Table 18. Specific information regarding each plot including locations, distances from the transect stake to the lakes edge and to the edge of the vegetation, compass bearing of the transect, and percent cover occupied by each vegetation type is presented in Appendix B and C.

Sedges, herbs, and grasses were the dominant plant types found in the upper portions of these plots. A native shrub, sweet gale (*Myrica gale*), was very abundant at several sites. As expected, aquatic plants occurred in the lowest plots in or near the lake.

We reexamined these transects in December 1994 when the lake had risen and each of the marker stakes (located at the upland end of the transect) was partially submerged except at Cemetery Point (Transect B) and Olsen's Beach (Transect D). The stakes at these two sites were approximately 0.3 m above the lake surface and 1.0 m from the water's edge. Sweet gale, sedges, and grasses were observed on this date at some transects to depths of approximately two meters and in areas where active sockeye spawning was occurring (Olsen's Beach) or had been reported in the past (Umbrella Point).

No further analysis of the vegetation plots was conducted but the transects were marked with semi-permanent stakes and should be reexamined in the future to assess gross changes in species composition, coverage, and potential encroachment into the lake.

Tributaries to Lake Ozette

Water Temperature: Continuous sampling using thermographs in the tributaries to Lake Ozette documented relatively high water temperatures during July and August, 1994 (Figure 9 and Appendix D Tables 1-6). Maximum daily water temperatures reached 20.3, 19.1, 18.4, and 17.4°C in Crooked, Umbrella, South, and Siwash Creeks, respectively. Water temperatures in the Ozette River also were relatively high, often exceeding 20° C although these data reflect the lake's surface water temperature as our sample site was located a short distance below the lake.

The probe on the thermograph placed in Big River was exposed to air sometime after deployment, and maximum water temperatures in this stream could not be determined with certainty.

Dissolved Oxygen: Monthly sampling in the lake's tributaries documented levels of dissolved oxygen from 5.71 to 12.66 mg/L (Tables 19-26). Coal Creek exhibited the lowest DO levels that included one value as low as 5.71 mg/L on August 25, 1994 (Table 21). This stream has a very low gradient at the point where our monitoring occurred which probably contributed to these low levels.

pH: The pH values in each of the tributaries to the lake declined to relatively low levels at certain times of the year, primarily during high discharges associated with winter storms (Tables 19-26). Crooked Creek exhibited the greatest variation ranging from 5.71 to 7.20 while Coal Creek exhibited very low values throughout the entire year ranging from 5.74 to 6.82.

Specific Conductance: Streams flowing into Lake Ozette are generally of low conductivity and no trends were noted although readings were inversely related to discharge (Tables 19-26). Specific conductivity ranged from 17.9 to 100.5 uS/cm with the greatest variation occurring in Umbrella Creek.

Turbidity: During storm events and high discharge, Lake Ozette tributaries exhibited high turbidity levels, particularly on Big River and Umbrella Creek (Tables 19-26). Peak readings on these streams were 185 and 161 NTU's, respectively. These highly turbid conditions were recorded on November 30, 1994 following a storm event. During moderate to high flow conditions, Big River consistently exhibited the highest turbidity levels.

Fish Species Composition: The predominant species of fish in Siwash Creek during mid-summer were sculpins followed by cutthroat with small numbers of juvenile coho and lamprey (Table 27). No rainbow/juvenile steelhead were found in Siwash Creek. Sample sites included low and moderate gradients favored by juvenile coho and steelhead, respectively. Only three juvenile coho were captured in all sites combined and none were found in the upper site. Phinney and Bucknell (1975) did not list any barriers to salmonid migration between the reaches we sampled and none were observed during subsequent foot surveys.

Fish species composition in Big River included juvenile coho, rainbow/juvenile steelhead, and sculpins (Table 28). Sculpins were the predominant species again with very low salmonid densities, especially juvenile coho, although our electrofishing efforts were not designed to assess relative abundance. This stream exhibited a low gradient throughout all four reaches.

DISCUSSION

Limnological Conditions in Lake Ozette

Lake Ozette can be most closely categorized as a warm monomictic lake based on results from our study and definitions of lake type in Wetzel (1983). Temperatures do not drop below 4° C, the lake circulates freely throughout winter at or above 4° C with no inverse stratification, and it exhibits thermal stratification during summer months. In addition, Lake Ozette is found in a warm temperate region with weather influenced by oceanic conditions.

Year round water quality monitoring at the four lake stations indicated generally favorable conditions (temperature, dissolved oxygen, and pH) for adult and juvenile sockeye as well as other salmonids. Adult sockeye spend five months or more maturing in the lake prior to spawning and juveniles typically spend one year rearing in the lake (Dlugokenski 1981; Blum 1988). Juvenile coho, steelhead, and cutthroat are also believed to spend variable periods of time rearing in the lake.

Brett (1983) and Kyle et al. (1988) found that adult sockeye generally prefer water temperatures less than 15°C and dissolved oxygen levels greater than 5 mg/L. The upper 3 m of Lake Ozette exceeded the preferred temperature range from July through September 1994, but below approximately 12 m the lake remains within the preferred range

throughout the entire year. Dissolved oxygen throughout the lake's water column is normally well above the required range throughout the year. The relatively low dissolved oxygen concentrations evident in the metalimnion from August through October are not a threat to fish and may be attributed to reduced sinking rates of particulates in the denser water of this strata increasing the time for material to decompose. Also, oxidative processes by zooplankton assemblages may contribute to the low concentrations of dissolved oxygen.

Overall, pH values in Lake Ozette were within the range of 6.0 - 9.0 reported by Wetzel (1983) for most lakes as were other water quality variables (conductivity, redox). During much of the year, turbidity does not appear to be a threat to juvenile or adult salmonids although they may avoid some areas of the eastern shoreline during winter storms when turbidity levels increase to 25 NTU or more. In a review of the literature, Cook-Tabor (1994) cites several studies which reported negative effects on feeding by salmonids at 15-30 NTU and gill tissue damage occurred in fish when exposed to turbidity levels of 25 NTU over five to seven days.

Analysis of water chemistry, nutrients, and densities of zooplankton and chlorophyll in Lake Ozette produced values comparable to other sockeye producing lakes in Washington, British Columbia and Alaska. Based on these values, there was no indication of a lack of productivity in the lake. Blum (1988) provided further evidence of the lake's productivity based on the presence of large sockeye smolts that were the second longest and third heaviest smolts reported in the literature. Productivity and availability of prey to juvenile sockeye does not appear to be a limiting factor under present stock sizes in Lake Ozette.

To determine whether obvious changes in water quality have occurred, we compared water quality variables from Station 1 at 30 m (this site and depth had the most comparable samples) and average Seechi disk readings from all four lake stations to those samples collected in 1976 by Bortleson and Dion (1979). There was little difference in conductivity, pH, temperature, and dissolved oxygen (Figure 10) at Station 1 between years. However, water clarity, as measured by Seechi disk readings, appeared to be substantially greater in 1994 (Figure 11). The higher clarity in 1994 may have been due, at least in part, to much lower zooplankton densities than those reported by Bortleson and Dion (1979). These differences may also be explained by seasonal, annual, and sampling variability. In addition to differences in water clarity, the 1994 samples exhibited higher nitrate and nitrite concentrations at the four stations when compared to the 1976 samples although these differences may again be due natural and sampling variability (Figure 12).

Water Quality Conditions in the Ozette River and Tributaries to Lake Ozette

Water quality conditions in the Ozette River and the lake's tributaries are generally suitable for salmonid spawning and rearing with some exceptions. Results from this study suggest that elevated water temperatures in the upper Ozette

River may impede or prevent upstream migration of adult sockeye in mid-summer. Bjornn and Reiser (1991) reported immigration delays for sockeye at water temperatures greater than 21.1°C. Maximum and minimum water temperatures in the upper Ozette River after June 21 were above the preferred range for sockeye (7.2-15.6°C) and by July 19, maximum daily temperatures at the lake outlet exceeded the 21.1°C. By early August, minimum daily temperatures also exceeded this threshold. A maximum river water temperature of 23.7°C was recorded on August 5.

High water temperatures in the Ozette River near the lake outlet likely result from solar heating of the surface waters of Lake Ozette and are a natural condition. In 1926, Kemmerich (1945) also reported water temperatures of 18-22°C in the same portion of the Ozette River during the last half of June. The rapid increase in water temperatures in this portion of the Ozette River may be one of the principal factors in the early return timing of Ozette sockeye compared to other populations in Washington and British Columbia (the Lake Quinault stock also returns early). Jacobs et al. (1996) summarized weir catches of Ozette sockeye by the Makah Tribe near the lake outlet. These catches are of sockeye that have recently entered the Ozette River (probably within 48 hours; Dlugokenski et al. 1981) and are about to enter the lake. Jacob's summary decribes entry into the lake beginning in late May and continuing into early August with a peak in late June. This entry timing is similar to that exhibited by the nearby Quinault sockeye population but very different from the larger returns of sockeye to the Fraser River where entry into the lower river occurs primarily in late summer and fall. Generally, other water quality variables in the Ozette River are not in a range that would prevent salmonids from migrating, spawning, or rearing in the Ozette River.

Water quality conditions in the tributaries to Lake Ozette are marginal and, for some variables, exceed existing limits designed to protect fish and aquatic life. Washington State criteria for Class AA waters (applicable to waters in national parks and critical habitat for populations of threatened or endangered species of native anadromous fish) requires that water temperature not exceed 16.0°C due to human activities. When these waters do exceed this threshold, it should not be by more than 0.3° C. In addition to this criteria, the Washington State Forest Practices Act only allows streams to remain at or above 16.3°C for 10 consecutive days between the period of July 15 - August 15. Umbrella, Crooked, Siwash, and South Creeks exceeded 16.3° C routinely during the summer of 1994 (Big River water temperatures reached 16.3°C in late August but no useable data were available before this date since the probe was out of water at some point prior to August 25). In addition, Umbrella and Crooked Creeks exceeded the Forest Practices criteria during the critical period of July 15 - August 15 when both streams remained above 16.3°C for 29 days.

Dissolved oxygen and pH levels in the Ozette tributaries were near or below the lower end of the acceptable range for salmonids. Washington State water quality standards for dissolved oxygen in Class AA streams require that levels remain above 9.5 mg/L. Monthly sampling in South Creek, Crooked Creek, and Big River, documented dissolved oxygen levels less than 8.00 mg/L during summer months. The EPA recommends pH values between 6.5 and 9.0 to

protect aquatic life and the State of Washington requires its waters to remain within a range of 6.5 to 8.5 with human caused variations not to exceed 0.2 units. In each of Lake Ozette's tributaries, pH was less than the state and federal standard of 6.5. Crooked and Coal Creeks exhibited pH values below 6.0, a value at which salmonid egg development and hatching success decrease and emergence of some aquatic insects decline (MacDonald et al.1991). The lowest pH readings generally occurred during winter storms and high stream discharge. Winter freshets are relatively frequent in the Ozette basin during the salmonid egg incubation period.

High flows accompanying storm events also resulted in high turbidity levels. The State of Washington has established criteria for turbidity in Class AA streams which states that "turbidity shall not exceed 5 NTU over background turbidity when the background turbidity is 50 NTU or less, or have more than a 10 percent increase in turbidity when the background turbidity is more than 50 NTU." Unfortunately, there is no information regarding background turbidity levels for the lake's tributaries although the highest turbidity levels measured in Big River and Umbrella Creek (NTU's of 161 and 185, respectively) were much greater than the level at which salmonids are impacted. Short term negative effects of high turbidity include: the deposition of fine sediment that may significantly degraded spawning habitat and reduce survival of steelhead from egg to emergence (Phillips et al. 1975), sublethal effects from suspended sediment (e.g. elevated blood sugars and cough rates, Sevizi and Martens 992); physiological stress and reduced growth; loss of inter-gravel cover for fish from increased sediment levels (Spence et al. 1996); avoidance of suspended sediments by juvenile salmonids (Bisson and Bilby 1982; Sevizi and Martens 1992); and elevated turbidity levels can reduced the ability of salmonids to detect prey and may cause gill damage (Sigler 1980; Lloyd et al. 1987). Moderate turbidity levels (11 to 49 NTU's) also may cause juvenile steelhead and coho to leave rearing areas (Sigler et al 1984). Additionally, short-term pulses of suspended sediment have been shown to influence territorial, gill-flaring and feeding behavior of salmon under laboratory conditions (Berg and Northcote 1985).

Although there are no existing standards for discharge, wide fluctuations were evident in the Lake Ozette tributaries. During summer months, discharge dropped below 0.03 cm/s (one cubic foot per second) on each of the tributaries except Big River where the minimum flow measured was 0.05 cm/s. Bortleson and Dion (1979) estimated discharge from stage recorders on Big River and Umbrella Creek in 1976-77 and found peak discharges of close to 17 and 11 cm/s (600 and 388 cfs), respectively. We observed rapid changes in discharge in the tributaries, but were unable to measure the highest flows as the streams were not wadeable during these events. On several occasions, the tributaries over-flowed their banks and spread across the forest floor.

Potential Factors in the Decline of Ozette Sockeye

The most compelling argument for the decline of Ozette sockeye is based on gill net catches by Makah Tribal fisherman, which declined from a peak of 17,638 in 1949 down to 49 in 1973. Presumably these catches are an

indicator of relative annual abundance but no estimates of fishing effort were reported during this period so it can not be determined with certainty whether an actual decline occurred or if the amount of fishing effort had simply been reduced. Kemmerich (1945) provides additional insight into the historic abundance of sockeye returns to Lake Ozette. He operated a weir located near the lake outlet and trapped a total of 3,241, 6,343, and 2,210 adult sockeye in 1924 (trap operated from May 27 – August 8), 1925 (June 8- September 15), and 1926 (June 10 – September 9), respectively. While there were probably some sockeye that escaped past his weir and some unknown number caught in tribal fisheries, Kemmerich's (1945) weir counts were collected 24 years prior to the time when tribal catch reporting began and are probably better representations of early spawning escapement.

Large cyclic, fluctuations in sockeye run sizes are typical of this species and catches as large as 17,000 from a normally much smaller run would not be surprising. The Olympic Peninsula's largest natural run of sockeye returns to Lake Quinault and catches from this population have exceeded 500,000 but in most years are well below 100,000 (Figure 13). If catch record keeping for Ozette sockeye began on one of these high cycles, then the 1949-51 landings may only indicate the range of productivity of the stock. At the same time, escapement estimates gathered from the weir since 1977 suggest that spawning escapement of Ozette sockeye has declined well below those reported by Kemmerich (1945) in 1924-26 and the stock no longer appears to have the ability to produce large peak runs capable of producing the type of catches recorded from 1949-51.

Numerous factors are likely involved in the decline of Ozette sockeye including overfishing, the introduction of non-native fishes as early as 1929 (Port Angeles Evening News, August 17, 1929), predation by native cutthroat and pikeminnow (Beauchamp et al. 1995), degraded water quality, and other impacts associated with extensive logging in the basin. We suspect the degraded water quality conditions observed in this study in the tributaries and along the eastern shoreline of Lake Ozette are factors in the decline of Ozette sockeye and are related to the amount of disturbance in the watershed, especially extensive clear-cut logging, conversion to hardwood dominated riparian areas, and high gravel road densities. Large portions of the Ozette watershed have been clear-cut logged since 1960 (Buck Adamire, personnel communication). These timber harvest activities are reflected in the existing forest stand age. Based on an analysis of aerial photographs by Doug Morrill (Lower Elwha Tribe), we calculated the percent age composition of the forest community in the major tributary basins (Big River, Umbrella, Crooked, Siwash, and South Creeks) and found that approximately 50% of the trees in each drainage are less than or equal to 20 years of age (Table 30). The percentage of trees less than or equal to 40 years of age is at least 69% but ranges as high as 93% in the Umbrella Creek drainage.

It is likely that past land use practices have altered flow regimes in tributaries to Lake Ozette although this study did not specifically address changes in the frequency and magnitude of peak flows. Blum (1988) cites several authors who

report that clear-cut logging increases peak flows up to 30% depending on the amount of vegetation removed (see Anderson 1952; Anderson and Hobba 1959). Spence et al. (1996) also reported increased peak flows of up to 200% after logging in rain dominated systems such as Ozette, and noted that the magnitude of peak flows increased during flood events in the fall. It has also been reported that changes in peak flow are often more pronounced in small watersheds, such as the Ozette Basin (Hoyt and Langbein 1955). These increased peak flows result in a number of water quality and stream channel effects which negatively impact fish including slope and road failures, scour of salmonid redds (over 50% of the coho redds constructed in Big River in 1979 were scoured in December floods, WDFW spawner survey database), erode large quantities of fine sediment, increase erosive forces, and displace or strand juvenile fish.

Another potential contributor to the decline of Ozette sockeye is the effects associated with rates of change in lake levels. The removal of 26 logjams from the Ozette River (Kramer 1953) coupled with hydrologic changes in the basin may influence the rate at which the lake rises and falls. Changes in the rates at which the lake rises and falls during winter and spring could influence spawning success of shallow and later spawning sockeye. Although widely assumed to have spawned in the lake's tributaries historically, all documented sockeye spawning since the mid-1970's has occurred on the lake's beaches (the Makah Tribe initiated a sockeye fry planting program on Umbrella Creek and releases from that facility are now spawning in Lake Ozette tributaries). Surveys of the lake's beach spawning sites in 1994 by Olympic National Park divers and boat surveys by Dlugokenski et al. (1981) documented moderate amounts of spawning at depths as shallow as 0.3 m. In some years, redds constructed in shallow water may become isolated from the lake and possibly desiccate as the lake level drops. The lake level records collected at the Ozette Ranger Station since 1981 indicate annual fluctuations vary from 1.34 to 2.84 m, and average 2.2 m (Table 29). Using Forester's (1968) estimate of the mean number of degree-day units required for sockeye eggs to incubate and hatch (576°C or 1,069°F) and mean monthly temperature in the upper three meters of the lake in 1993-94, the incubation period of Ozette sockeye eggs may extend into late May for later spawning fish. Based on average changes in lake level and these projected emergence times, the eggs and alevins incubating in redds constructed in less than one meter during December and January are generally not at risk of desiccation or isolation from the lake although redds constructed during the latter portion of the spawning period (especially from February - April) are more vulnerable to isolation from the lake prior to emergence. During years of rapid rise and fall in lake levels, such as the winters of 1990-91 and 1998-99, the lake drops more than a meter from winter to early spring (Figure 14) putting shallow redds and their eggs and alevins at risk.

The other probable impact of the recent timber harvest in the Ozette watershed is the relatively high levels of turbidity in each tributary and probable high rates of sediment transport. Numerous studies have identified increases in sediment yield following timber harvest. Furniss et al. (1991) reviewed nine studies which provided estimates of landslides

resulting from various sources and found that slides and sediment yield from logging roads was greater than all other forest activities combined and these activities resulted in sediment yields 26-346 times greater than undisturbed sites. The other source of sediment in logged watersheds is from erosional processes. Chamberlin et al. (1991) identified road surfaces, landings, skid trails, ditches, and disturbed clear-cut areas as potential sources of sediment to stream channels from erosion. Reid and Dunne (1984) reported a 40% increase in fine sediments from gravel-surfaced logging roads, which were heavily used by logging trucks. Cederholm et al. (1982) reported that the negative effects of fine sediment on salmonid spawning occurred when gravel road densities exceeded about 3% of the basin area in the Olympic Peninsula's Clearwater River. At road densities in excess of about 4% of the Clearwater basin, or about 2.5 km/km^2, fine sediment production increased by a factor of four over the natural rate. Road densities in Lake Ozette tributaries range from 2.03-3.09 km/km^2 (Table 30).

Evidence of high rates of sediment erosion and bed load transport in the lake's tributaries is available from McHenry et al. (1994) who collected and analyzed substrate samples from Umbrella, Big, Crooked, and Siwash Creeks and other Olympic Peninsula streams. They found that Lake Ozette tributaries had the highest proportion of fine sediment (18.7%) of any of the rivers they sampled on the north Olympic Peninsula. Peterson et al. (1992) recommended a target level of fine sediment at less than 11% to protect habitat for salmonid spawning and egg incubation.

While information related to rates of sediment transport are beyond the scope of this study, it is apparent that the substrate on the beach at the mouth of Umbrella Creek is of poor quality and no longer suitable for successful salmon spawning. The conditions at this site have apparently changed in the last 20 years as Dlugokenski et al. (1981) observed approximately 30 sockeye spawning on this beach on January 20, 1979. No spawning activity has been reported at this site since that date. We surveyed the area on December 14, 1994 and January 13, 1995 and did not observe any evidence of spawning activity. The substrate composition in this entire area is now composed of fine-grained sand, which is unsuitable for spawning. Native sedges and sweet gale plus exotic reed canary grass have become established at this site and were observed at depths of at least one meter during the winter. These plants are able to survive while submerged for extended periods and would not only impede any spawning activity but may also be trapping additional suspended sediment carried into the lake by Umbrella Creek (Dr. E. Schreiner, botanist at Olympic National Park, personnel communication). We suspect some degradation of the substrate has also occurred at Olson's Beach which is located a short distance north of the mouths of Elk and Siwash Creeks. Beschta and Jackson (1979), Scrivener (1988), and Hartman et al. (1987) report that when the source of sediment to a stream reach, or presumably a lakeshore spawning area, persists, fine sediment infiltrates the interstitial spaces of the gravel and impacts egg incubation and can continue over long periods of time. These impacts continue until the source of sediment is stopped and several "channel-modifying" flows occur (Chamberlin et al. 1991). We suspect that these effects may persist for a longer period of time in a lakeshore spawning area, which relies on wave action to erode fine sediments from the substrate.

Extensive clear-cut logging in recent years has also altered the composition of the riparian zone with hardwoods dominating many stream side corridors leading to higher summer water temperatures. While the warmest water temperatures occurred in the summer when any tributary spawning sockeye would have migrated to the lake, high temperatures are a threat to other salmonids that rear in tributaries such as coho, steelhead, and cutthroat.

The poor water quality, high levels of fine sediment, and extreme flood flows in the tributaries to Lake Ozette must be addressed before significant recovery of sockeye and other salmonids will occur. In light of findings regarding the persistence of fine sediment in interstitial species when the source of elevated sediment is not removed (Beschta and Jackson 1979, Scrivener 1988, and Hartman et al. 1987), it may be necessary to mechanically remove fine sediments and encroaching vegetation from some of the lakeshore spawning areas such as the area north of the mouth of Umbrella Creek. It will also be necessary to reduce any elevated levels of fine sediments still being transported to the lake by the tributaries. We believe significant recovery of Ozette sockeye will require a coordinated, basinwide approach that addresses natural and biological processes in the lake and the surrounding watershed.

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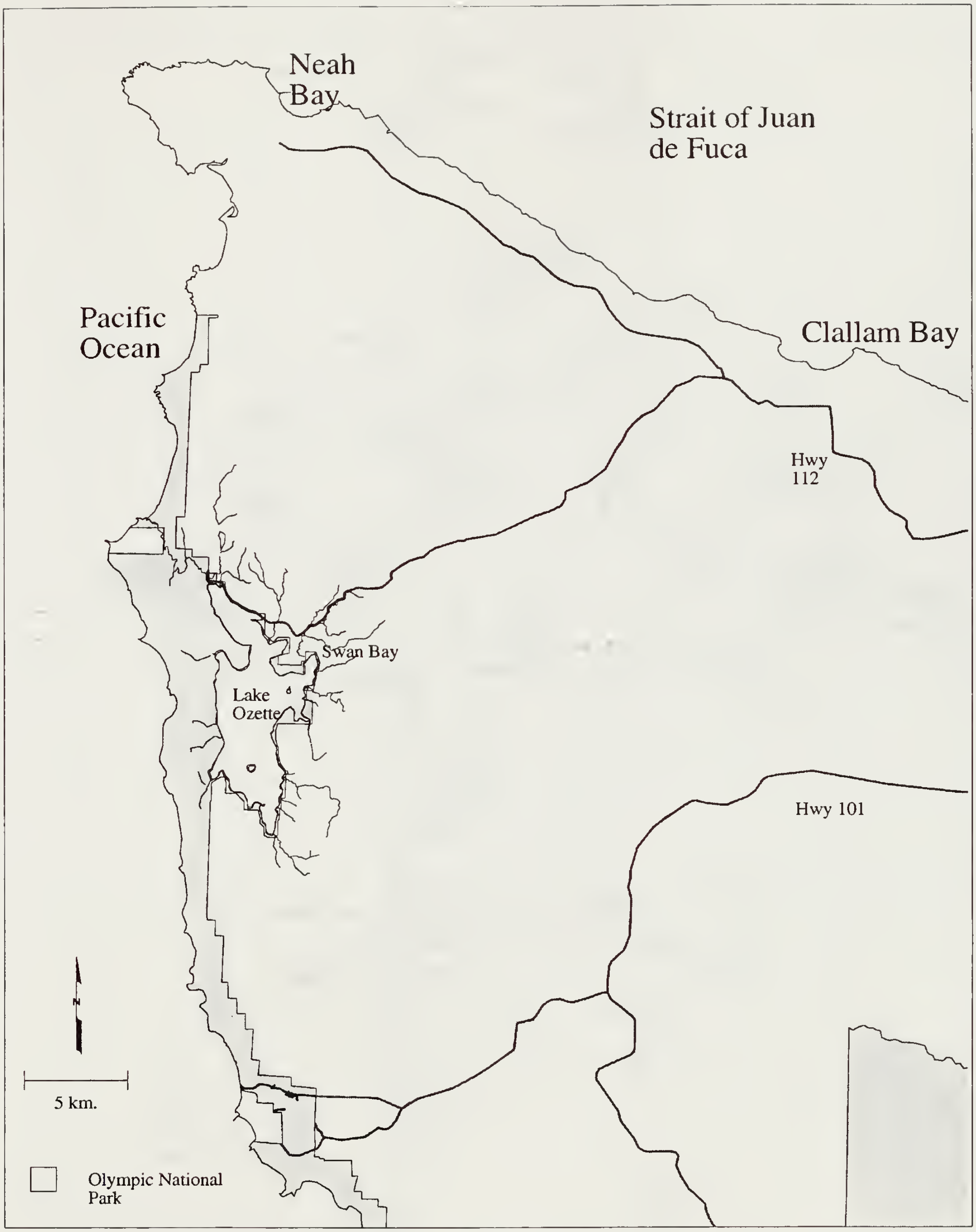


Figure 1. Area map of Lake Ozette.

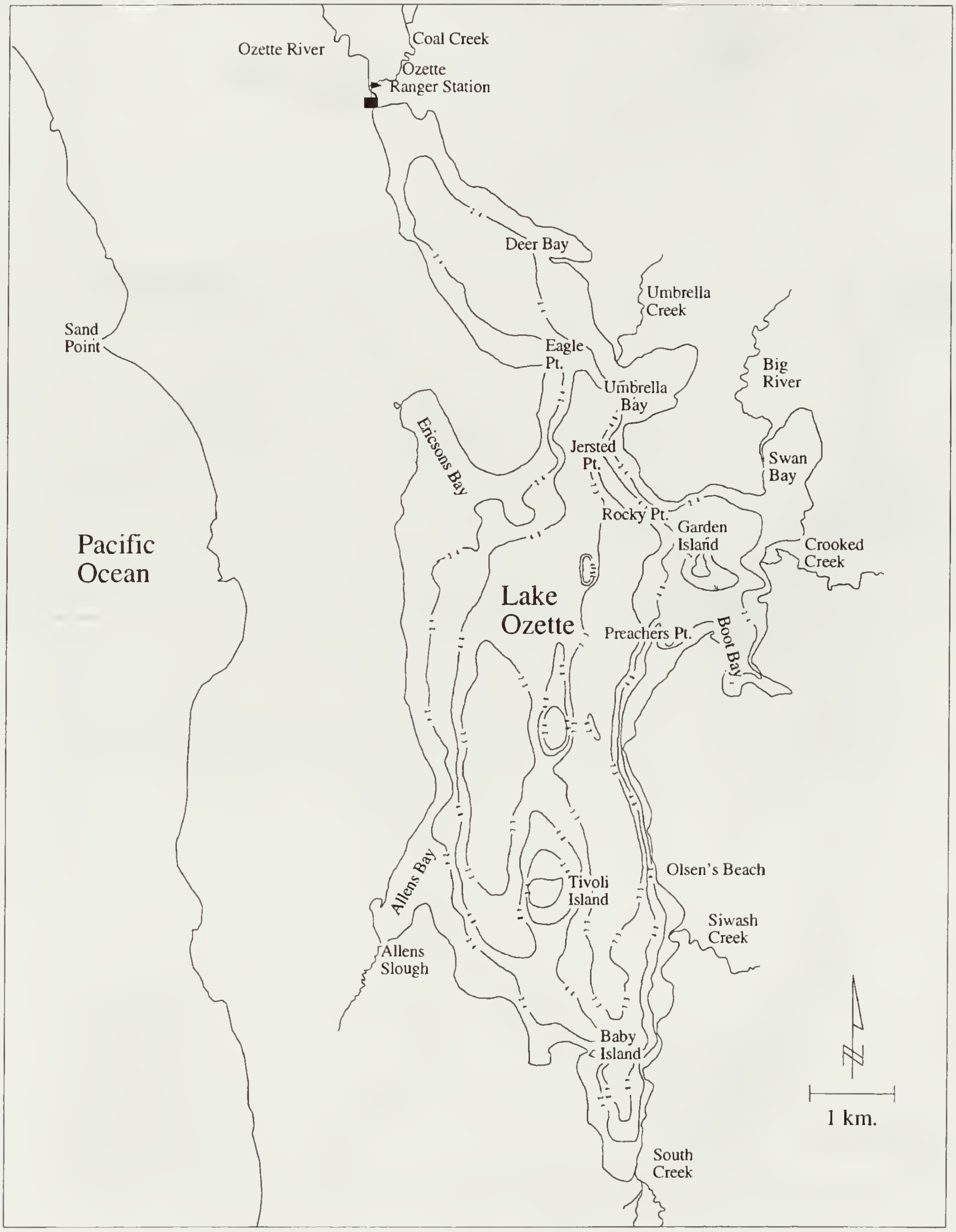


Figure 2. Depth contours (m) for Lake Ozette

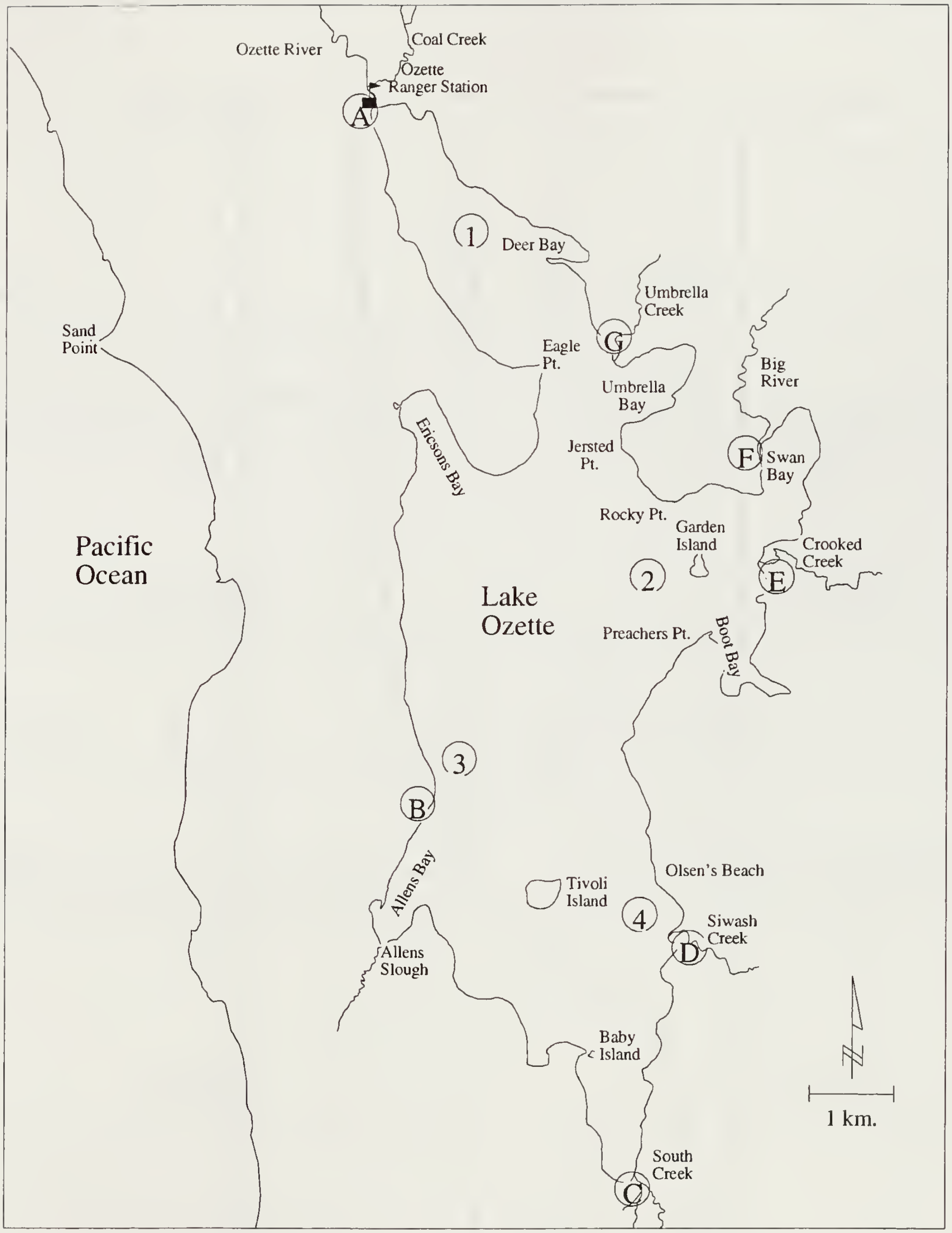


Figure 3. Location of water quality sampling stations (1 to 4) and vegetation transects (A to G) on Lake Ozette during 1993 and 1994.

Figure 4: Mean seasonal temperatures of Lake Ozette from the surface to 67m at water quality sampling Station 4, 1993-94.

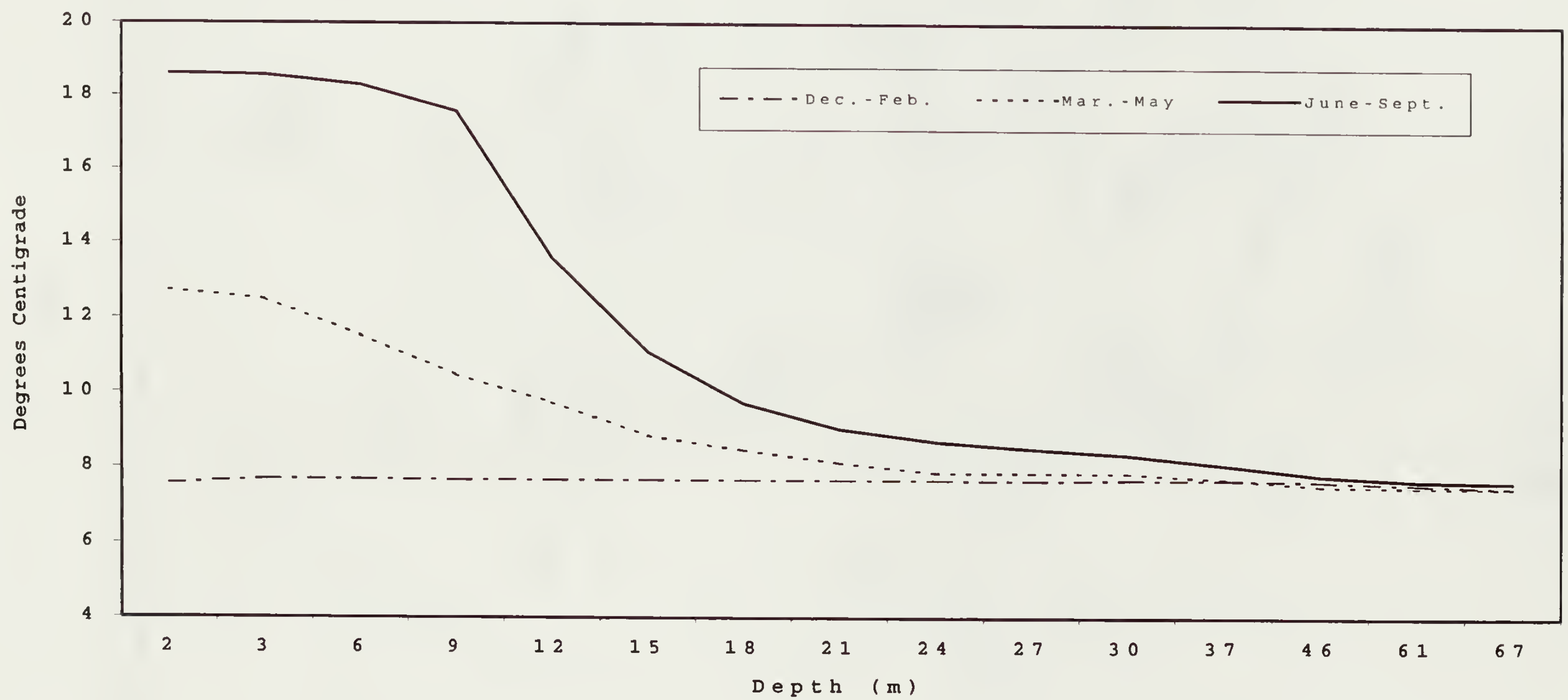


Figure 5. Monthly water temperature and dissolved oxygen profiles for Lake Ozette at Station 4, 1993-94.

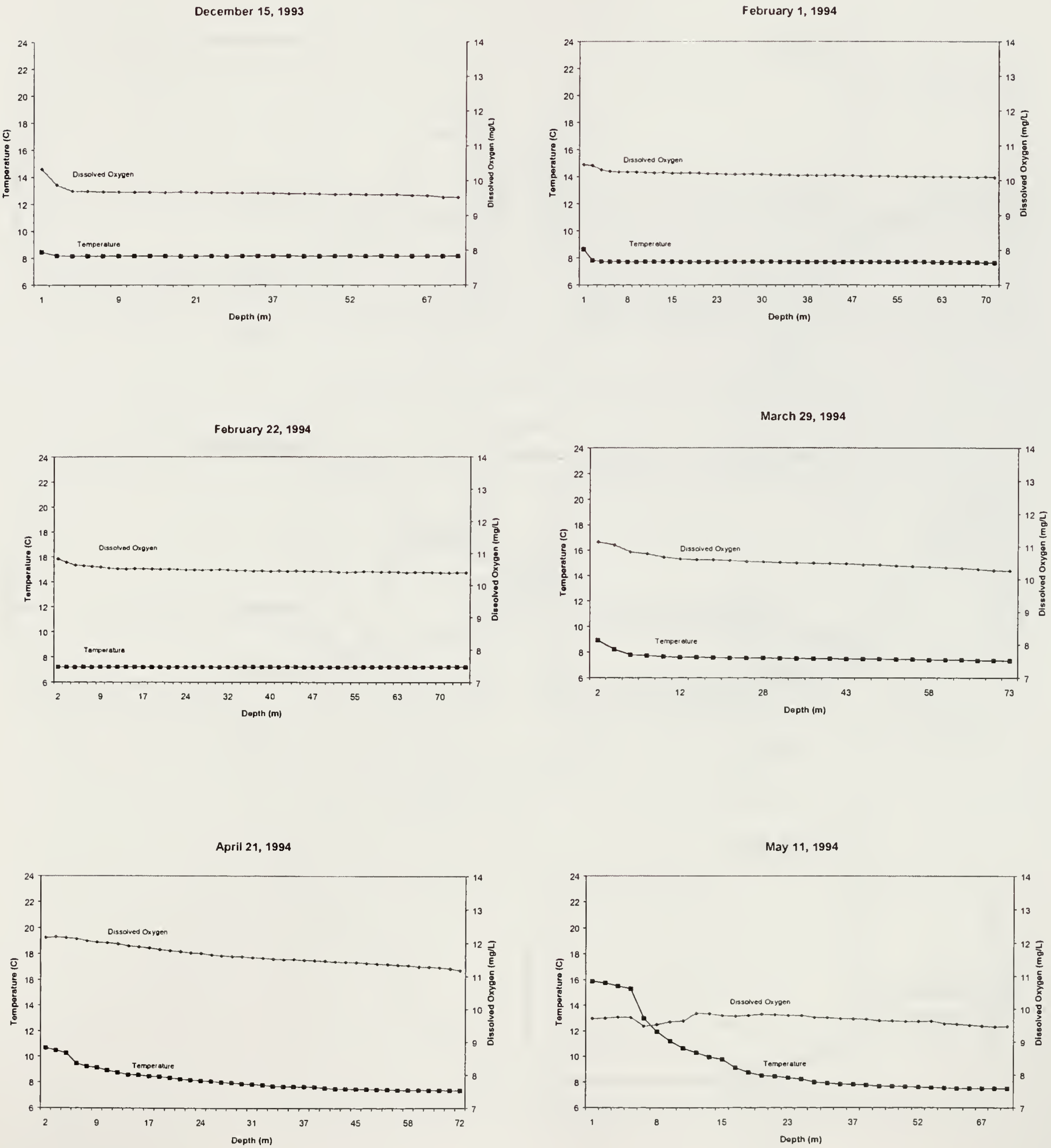
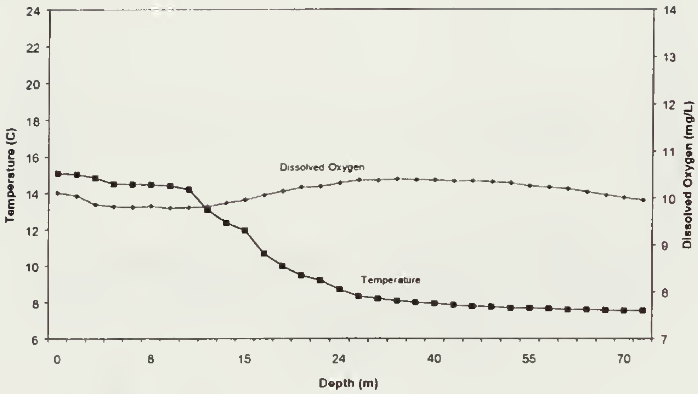
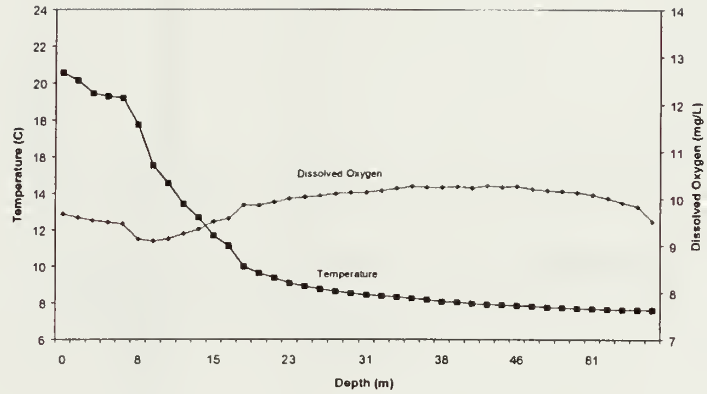


Figure 5 continued.

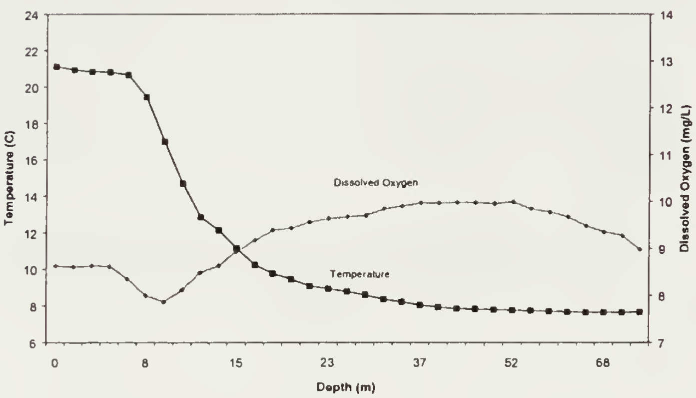
June 15, 1994



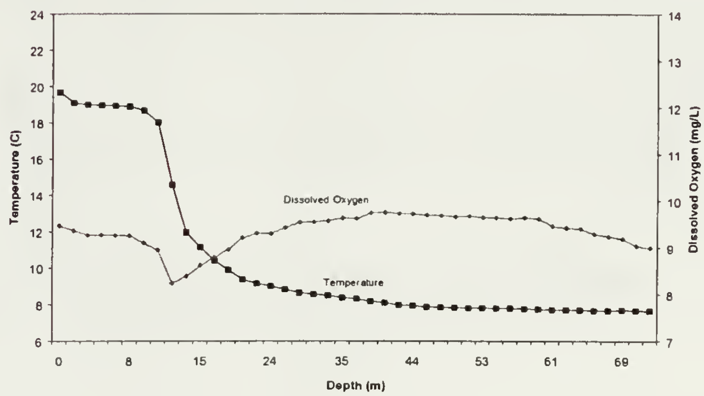
July 18, 1994



August 23, 1994



September 19, 1994



October 18, 1994

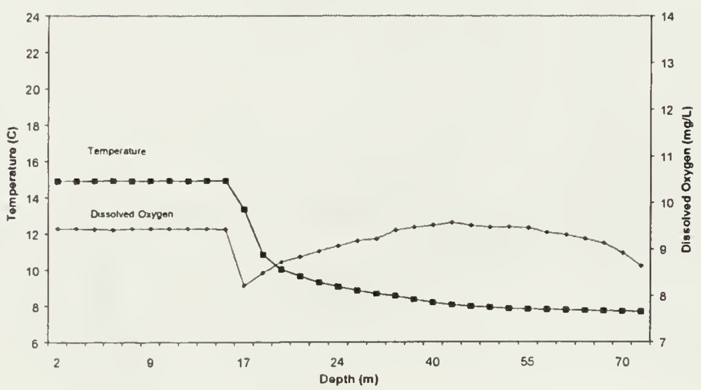


Figure 6. Seasonal pH profiles for Lake Ozette at Station 4, 1993-94.

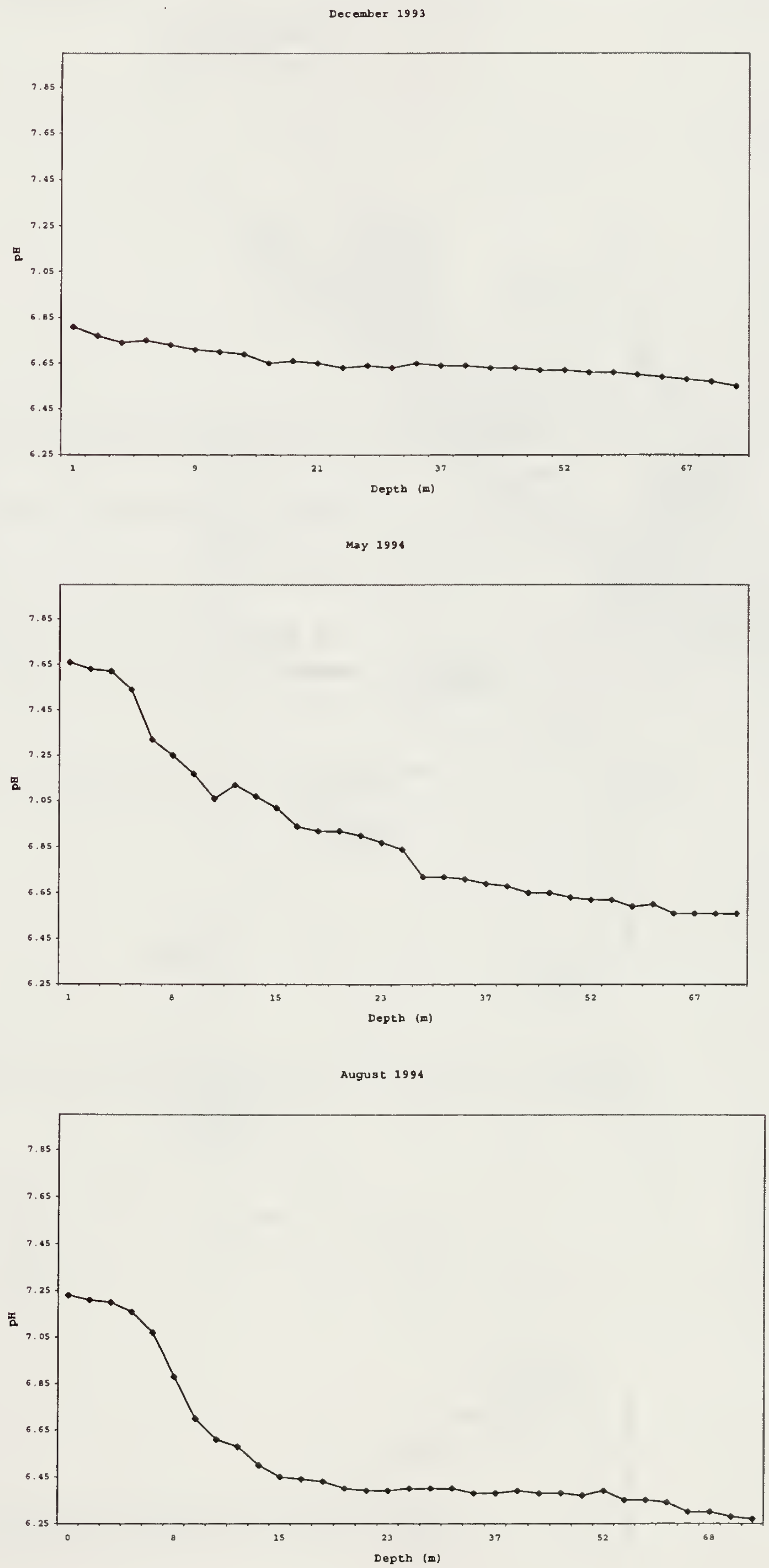
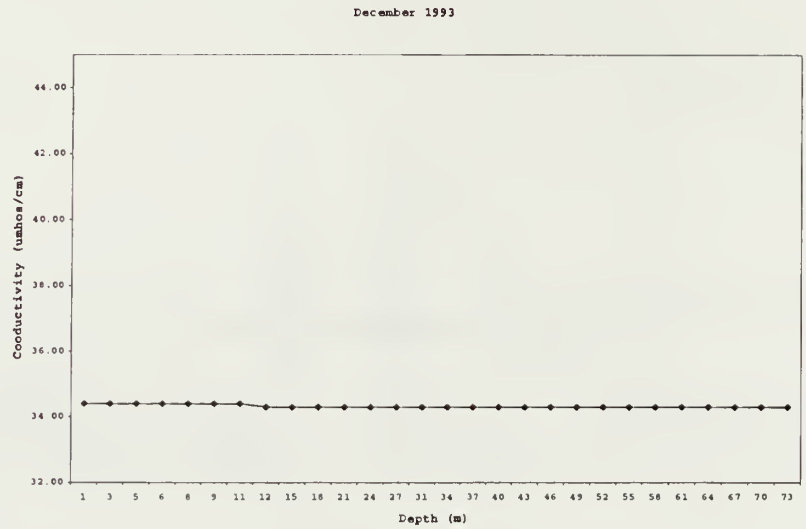
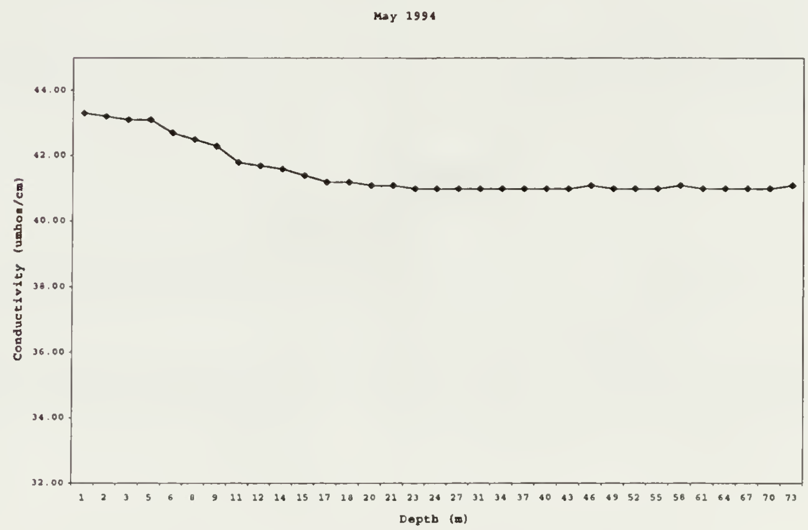
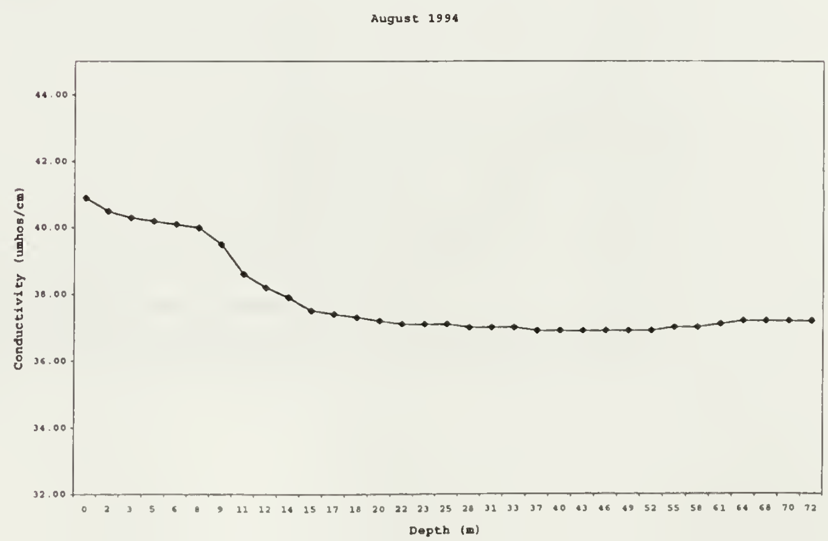


Figure 7. Seasonal profiles of conductivity for Lake Ozette at Station 4, 1993-94.







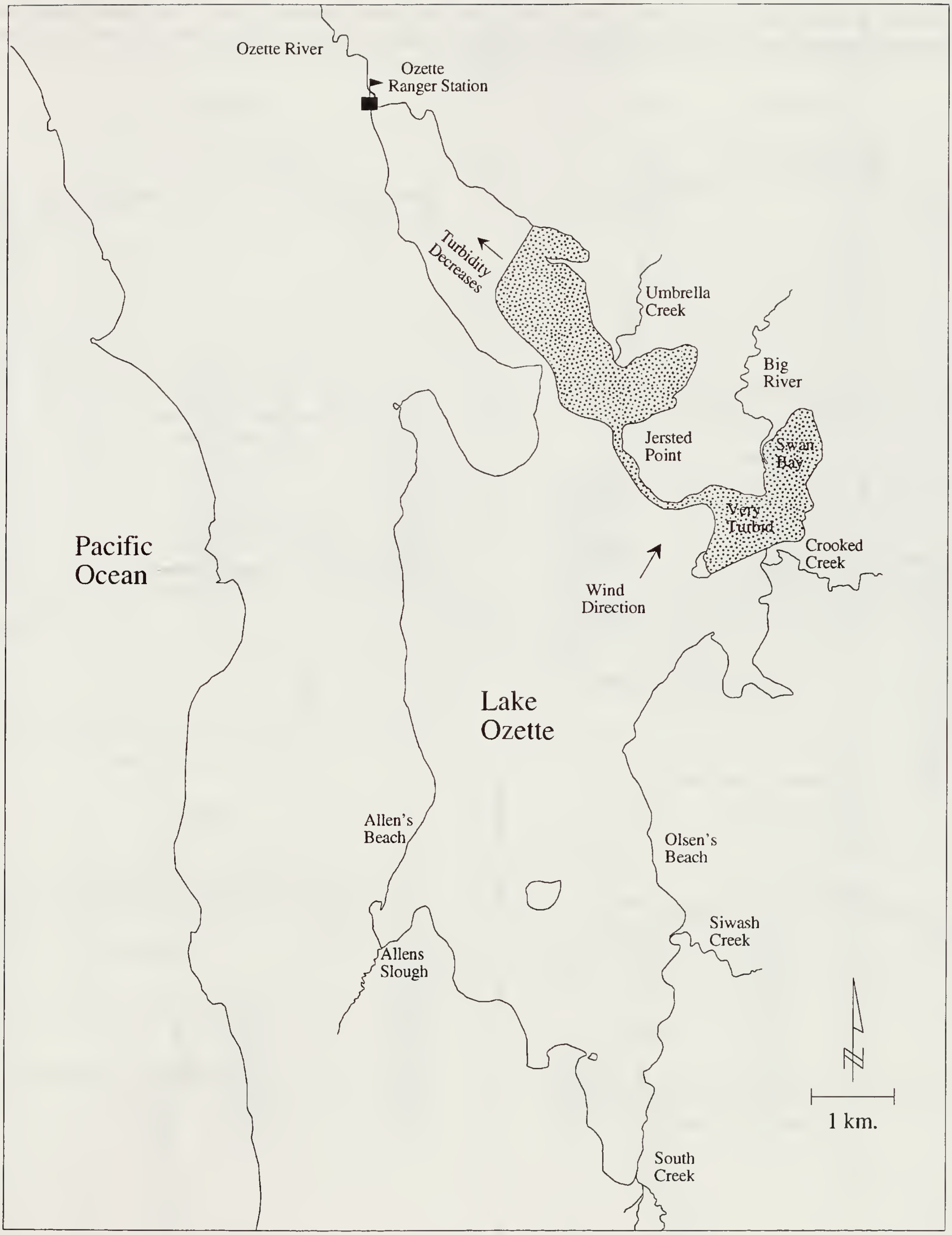


Figure 8. Turbidity plume on the surface of Lake Ozette on March 3, 1994.

Figure 9. Daily maximum and minimum water temperatures in the Lake Ozette tributaries, 1994. The thermograph probe in Big River was exposed to air sometime before August 25 and no reliable data were collected at this site prior to that date.

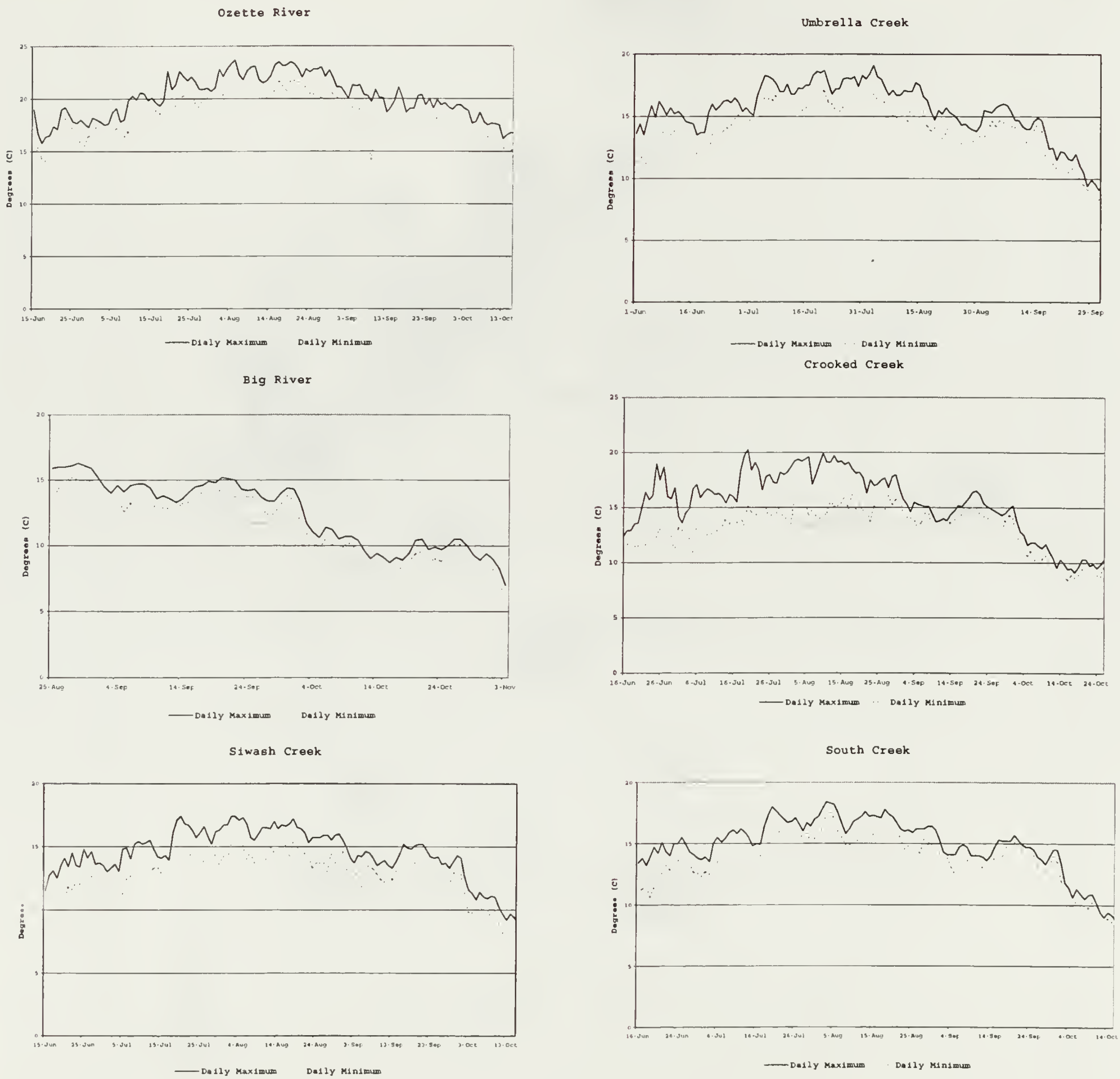


Figure 10. Comparison of seasonal water quality measurements collected at the bottom (30m) of Lake Ozette sampling Station 1, 1976 and 1994.

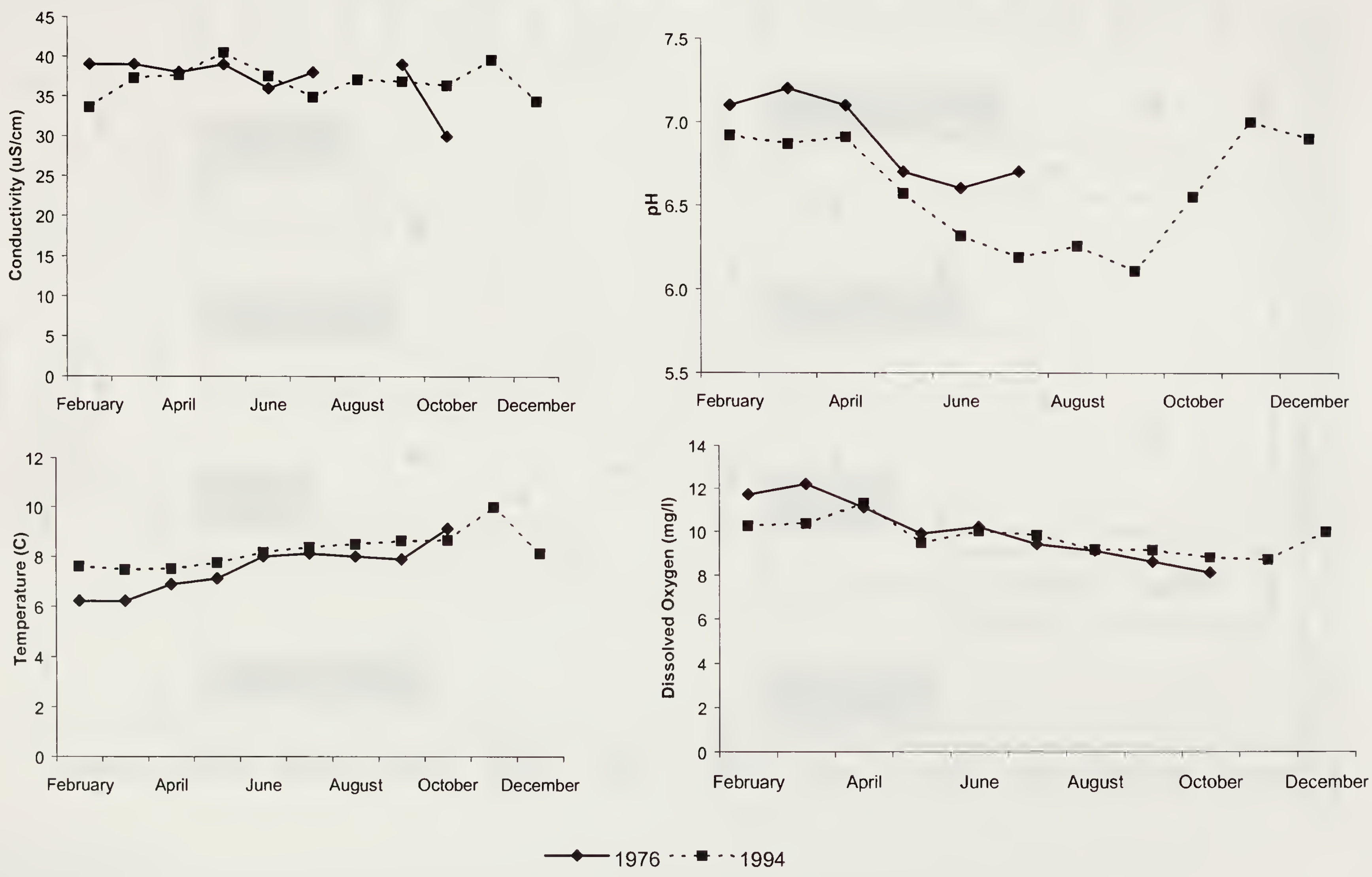


Figure 11. Comparison of average seasonal depth of Secchi disk readings for four sampling stations in Lake Ozette, 1976 and 1994.

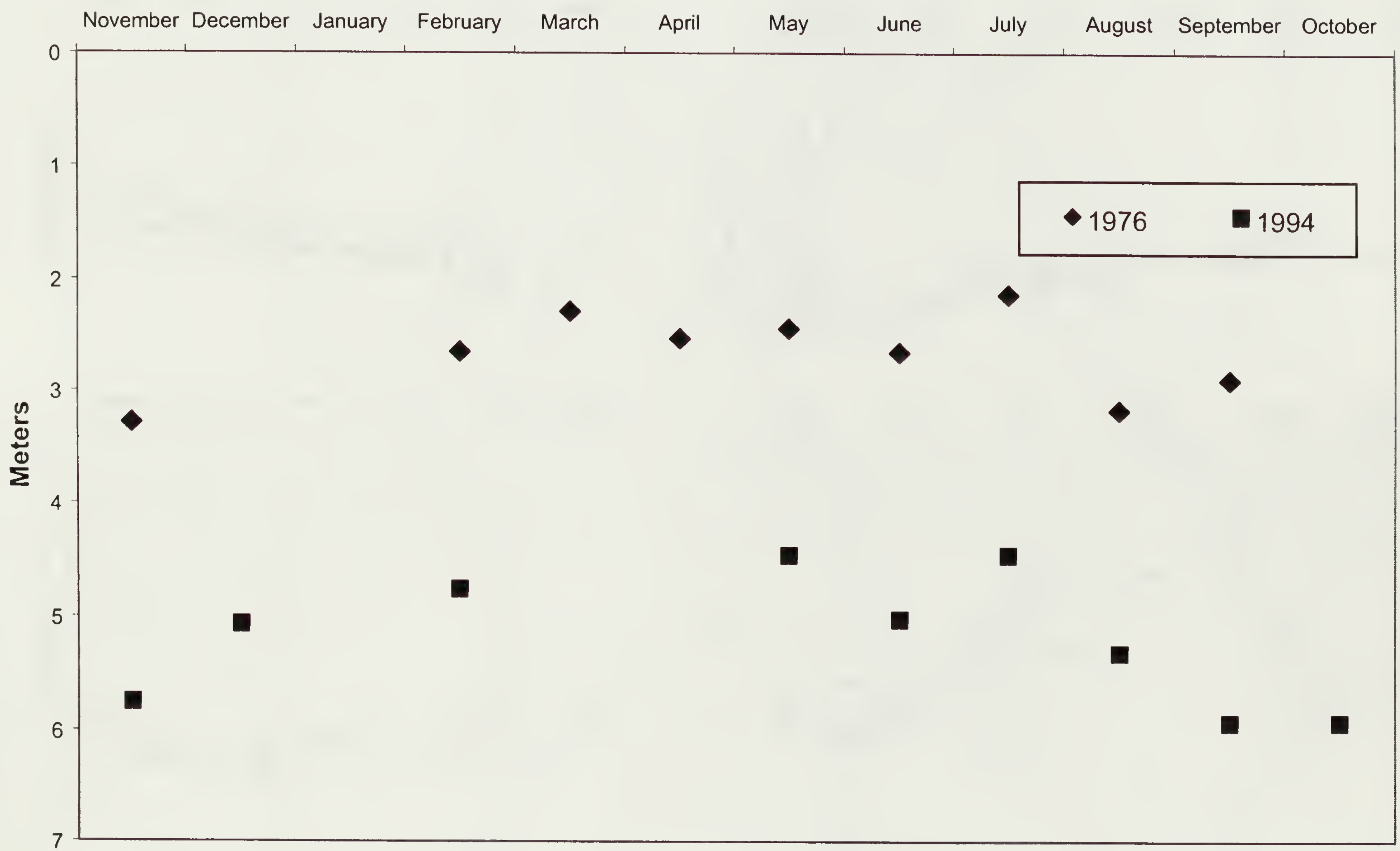
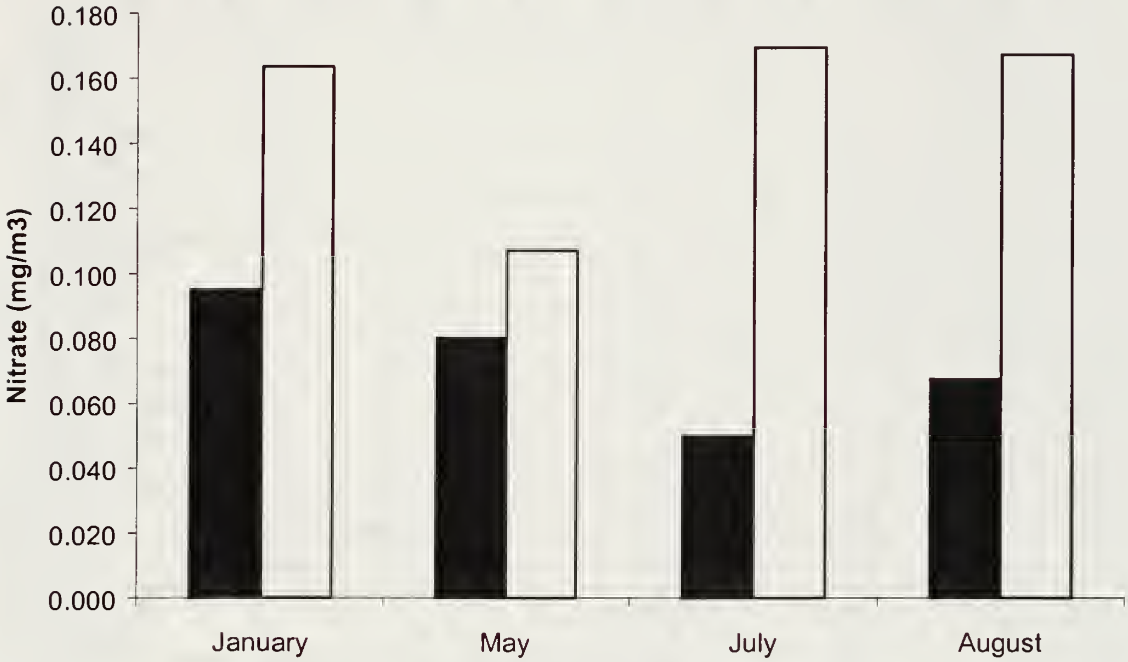


Figure 12. Comparison of seasonal nitrate and nitrite concentrations in water samples collected at 18 m from four sampling Stations in Lake Ozette, 1976 (Borleson and Dion, 1979) and 1994 (mean of four stations).



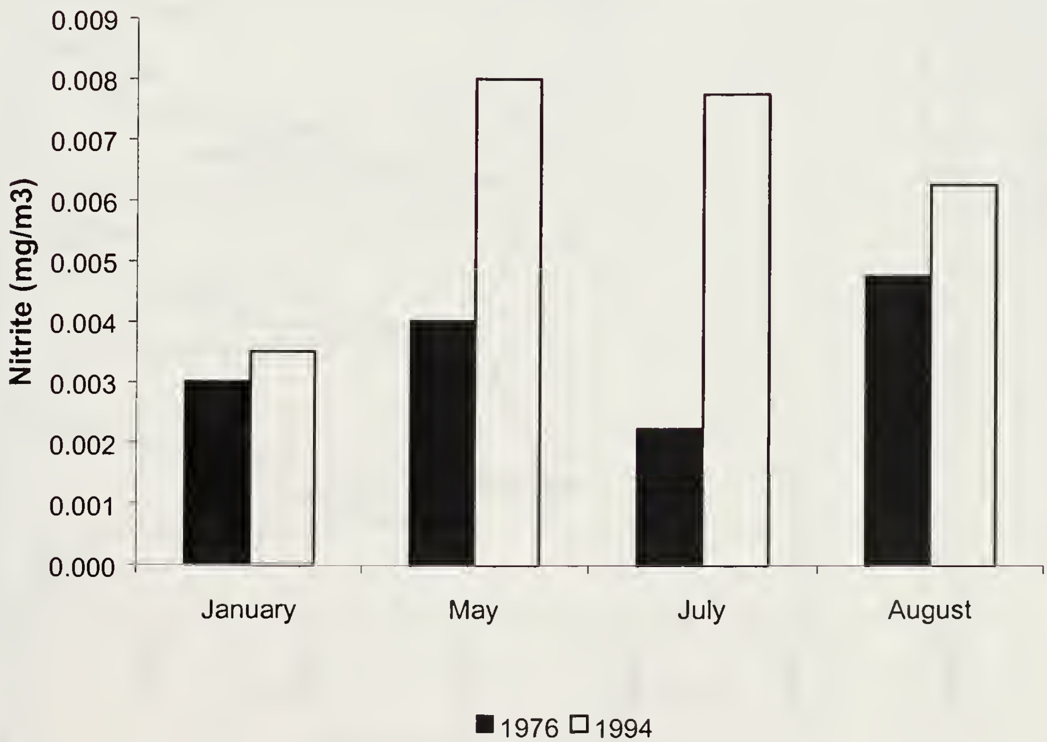


Figure 13. Historic trends and fluctuations in estimated run size and reported catch of Quinault and Ozette sockeye, respectively, 1910-1973.

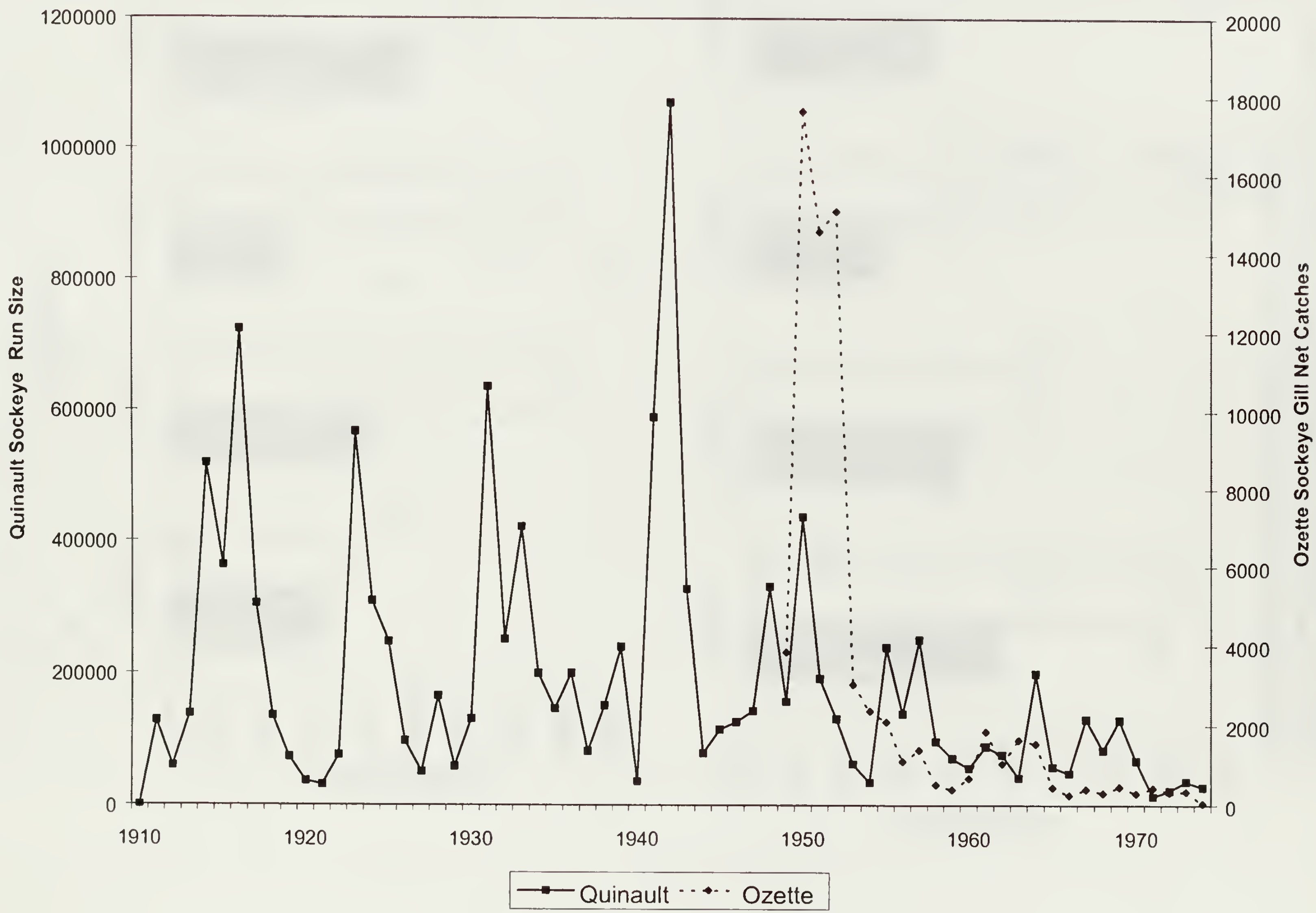


Figure 14. Comparison of mean monthly surface elevation of Lake Ozette from 1981-99 (lake level readings were not consistently recorded in 1995-97) and mean surface elevation during two wet years (1990-91 and 1998-99 water years) when the lake rose during the sockeye spawning period but dropped prior to emergence of the alevins from the gravel.

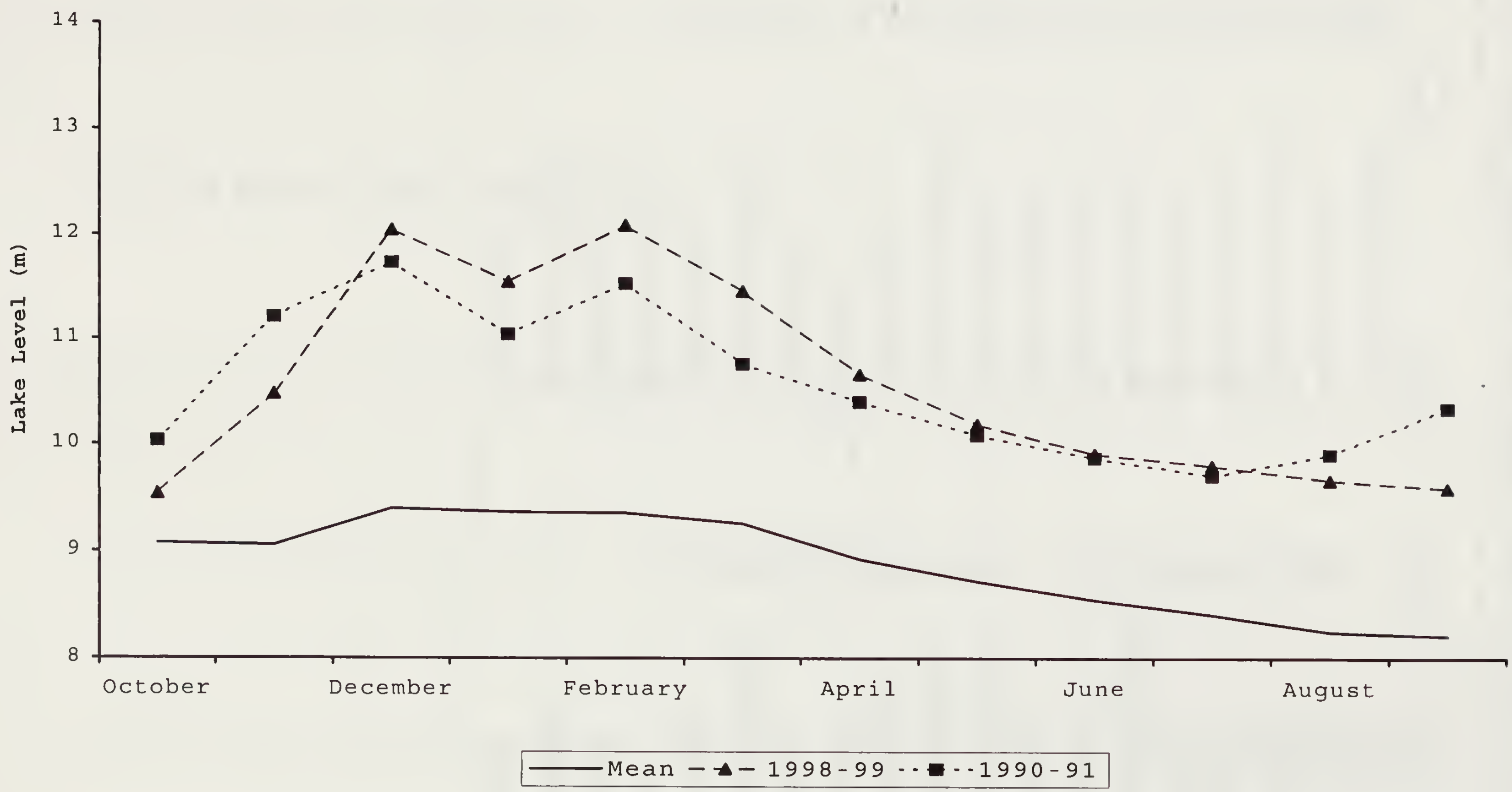


Table 1. List of fish species present in the Lake Ozette, Washington.

Sockeye salmon	*Oncorhynchus nerka*	Native
Kokanee salmon	*Oncorhynchus nerka*	Native
Chinook salmon	*Oncorhynchus tshawytscha*	Native
Coho salmon	*Oncorhynchus kisutch*	Native
Chum salmon	*Oncorhynchus keta*	Native
Rainbow/steelhead trout	*Oncorhynchus mykiss*	Native
Cutthroat trout	*Oncorhynchus clarki*	Native
Pacific lamprey	*Lampetra tridentata*	Native
Olympic mudminnow	*Novumbra hubbsi*	Native
Northern pikeminnow	*Ptychocheilus oregonensis*	Unknown
Reticulate sculpin	*Cottus perplexus*	Native
Prickly sculpin	*Cottus asper*	Native
Riffle sculpin	*Cottus gulosus*	Native
Threespine stickleback	*Gasterosteus aculeatus*	Native
Yellow bullhead	*Ictalurus natalis*	Non-native
Peamouth	*Mylochelius caurinus*	Unknown
Redside shiner	*Richardsonius balteatus*	Unknown
Largemouth bass	*Micropterus salmoides*	Non-native
Yellow perch	*Perca flavescens*	Non-native

Table 2. Gill net catches and sockeye escapement estimates from the Ozette River. Gill net catches landed by the Makah Tribe. Sockeye escapement estimated from weir counts by the US Fish and Wildlife Service and the Makah Tribe.

Year	Sockeye		Chinook	Coho	Chum
	Catch	Escapement			
1948	3850		491	1991	1063
1949	17638		1876	1527	1339
1950	14556		1629	2407	1226
1951	15074		1213	1103	1021
1952	3047		396	3697	682
1953	2380		431	906	431
1954	2110		823	862	907
1955	1107		404	1031	806
1956	1396		241	1149	0
1957	512		428	1119	0
1958	395		147	721	0
1959	682		0	0	0
1960	1851		0	0	0
1961	1054		3	281	0
1962	1645		0	385	0
1963	1551		1	263	1
1964	448		1	350	0
1965	257		1	407	0
1966	405		0	504	0
1967	313		0	272	0
1968	468		0	385	0
1969	295		0	189	0
1970	432		1	296	0
1971	328		0	244	0
1972	346		0	325	0
1973	49		0	0	0
1974	0		0	0	0
1975	0		33	0	0
1976	0				
1977	84	1004	0	0	0
1978	30	920	0	0	0
1979	30	540	0	0	0
1980	30	432	0	0	0
1981	0		0	7	0
1982	29	2147	0	15	0
1983	0	350	0	20	0
1984	0	2170	0	0	0
1985	0	0	0	80	2
1986	0	691	0	55	0
1987	0	0	0	0	0
1988	0	2191	0	0	0
1989	0	588	0	0	0
1990	0	263	0	0	0
1991	0	684	0	0	0
1992	0	2166	0	0	0
1993	0	<=267	0	0	0
1994	0	498	0	0	0
1995	0	314	0	0	0

Table 3. Range of water quality variables collected at Lake Ozette sampling Station 1 at 1m and on the bottom (approximately 27 m), December 1993 – October 1994.

Date	Temperature (^oC)		pH		Specific Conductivity (uS/cm)		Dissolved Oxygen (mg/L)		% Dissolved Oxygen Saturation		Turbitity (NTU)		Redox mV	
	1m	Bottom	1m	Bottom	1m	Bottom	1m	Bottom	1m	Bottom	1m	Bottom	1m	Bottom
Dec. 15	8.16	8.11	7.38	6.89	34.7	34.3	10.00	9.97	84	84	NA	NA	313	358
Feb. 1	7.79	7.58	7.00	6.92	33.7	33.6	10.36	10.27	86	86	NA	NA	521	380
Feb. 22	7.04	7.06	7.03	6.99	39.3	35.9	10.86	10.63	89	87	NA	NA	498	491
March 29	10.62	7.48	7.24	6.87	37.6	37.3	10.81	10.35	97	86	3.3	3.2	380	402
April 21	11.36	7.51	7.17	6.91	38.2	37.7	12.38	11.31	111	96	NA	NA	516	511
May 11	15.58	7.75	7.15	6.57	41.9	40.5	9.85	9.47	98	78	9.8	32.1	442	452
June 15	16.32	8.17	6.84	6.32	38.8	37.6	9.85	10.01	100	84	11.0	15.2	450	446
July 18	19.58	8.38	6.99	6.19	37.5	34.9	9.48	9.82	103	84	1.4	1.9	335	343
Aug. 23	21.74	8.50	6.86	6.26	40.6	37.1	9.25	9.17	106	75	2.5	2.1	385	378
Sept. 19	17.98	8.62	6.69	6.11	39.8	36.9	9.48	9.14	97	78	5.0	1.7	365	363
Oct. 18	14.83	8.66	7.74	6.55	38.6	36.4	9.44	8.80	93	75	9.2	5.7	361	352

Table 4. Range of water quality variables collected at Lake Ozette sampling Station 2 at 1m and at 74 m, December 1993 – October 1994.

Date	Temperature (^oC)		pH		Specific Conductivity (uS/cm)		Dissolved Oxygen (mg/L)		% Dissolved Oxygen Saturation		Turbitity (NTU)		Redox mV	
	1m	Bottom	1m	Bottom	1m	Bottom	1m	Bottom	1m	Bottom	1m	Bottom	1m	Bottom
Dec 15	8.22	8.15	7.03	6.72	34.5	34.3	9.77	9.64	82	81	NA	NA	406	417
Jan. 27	7.95	7.82	7.57	7.10	34.0	33.8	11.41	10.28	96	94	NA	NA	452	452
Feb. 1	8.06	7.60	6.98	6.81	33.7	33.6	10.26	10.08	86	83	NA	NA	484	479
Feb. 22	7.14	7.10	7.6	6.97	47.1	39.8	10.92	10.44	90	85	10.7	10.9	4169	432
March 29	10.50	7.39	6.80	8.08	37.7	37.6	10.58	11.46	94	84	NA	NA	515	512
May 11	15.76	7.50	7.11	6.55	41.8	40.5	9.68	9.60	96	79	15.5	35.0	470	476
June 15	15.55	7.66	7.01	6.38	39.7	37.9	9.93	10.34	98	86	18.0	3.0	398	401
July 18	19.40	7.70	7.60	6.44	37.8	35.1	10.10	10.19	108	85	1.4	1.8	274	312
Aug. 23	21.38	7.72	6.73	6.20	40.5	37.0	8.86	9.796	99	81	4.0	7.0	382	376
Sept. 19	19.08	7.76	7.04	6.27	39.6	36.7	9.35	9.58	100	81	1.9	5.7	341	336
Oct. 18	14.84	7.70	7.18	6.35	38.6	36.4	9.47	8.95	92	75	5.7	4.6	356	349

Table 5. Range of water quality variables collected at Lake Ozette sampling Station 3 at 1m and on the bottom (approximately 70 m), December 1993 – October 1994.

Date	Temperature (°C)		pH		Specific Conductivity (uS/cm)		Dissolved Oxygen (mg/L)		% Dissolved Oxygen Saturation		Turbitity (NTU)		Redox mV	
	1m	Bottom	1m	Bottom	1m	Bottom	1m	Bottom	1m	Bottom	1m	Bottom	1m	Bottom
Dec. 15	8.36	8.14	6.85	6.61	34.3	34.3	9.99	9.60	85	81	NA	NA	413	428
Feb. 1	7.87	7.70	6.97	6.85	33.9	33.6	10.36	10.08	86	84	NA	NA	500	490
Feb. 22	7.18	7.17	6.96	6.81	35.8	34.2	10.86	10.36	90	89	NA	NA	490	483
May 11	15.20	7.51	7.33	6.59	42.3	40.6	9.83	9.55	97	79	3.3	NA	449	459
June 15	15.23	7.54	7.01	6.48	39.3	37.9	10.33	10.05	102	83	13.4	2.4	428	425
July 18	19.94	7.58	7.06	6.19	37.4	35.1	9.08	9.55	97	79	1.4	1.7	322	332
Aug. 23	21.04	7.61	6.91	6.11	40.4	37.4	8.86	9.20	98	76	3.9	2.6	384	381
Sept. 19	19.03	7.63	7.11	6.16	39.5	37.1	9.38	8.36	101	69	1.8	2.4	342	345
Oct. 18	14.93	7.62	7.02	6.11	38.5	37.5	9.44	6.22	93	50	6.7	5.2	355	354

Table 6. Range of water quality variables collected at Lake Ozette sampling Station 4 at 1m and at 74 m, December 1993 – October 1994.

Date	Temperature (°C)		pH		Specific Conductivity (uS/cm)		Dissolved Oxygen (mg/L)		% Dissolved Oxygen Saturation		Turbitity (NTU)		Redox mV	
	1m	Bottom	1m	Bottom	1m	Bottom	1m	Bottom	1m	Bottom	1m	Bottom	1m	Bottom
Dec. 15	8.45	8.14	6.81	6.55	34.4	34.3	10.34	9.52	88	80	NA	NA	432	447
Feb. 1	8.64	7.64	6.85	6.89	34.3	33.7	10.456	10.08	99	84	NA	NA	484	470
Feb. 22	7.20	7.21	6.88	6.80	34.6	34.1	10.82	10.40	90	86	NA	NA	504	495
March 29	8.93	7.32	6.99	6.74	37.6	37.2	11.14	10.26	96	85	1.9	3.8	508	495
April 21	10.68	7.36	7.17	6.90	38.5	38.3	12.15	11.18	108	93	NA	NA	464	472
May 11	15.87	7.49	7.66	6.56	43.3	41.1	9.70	9.47	97	78	2.6	38.0	406	429
June 15	15.09	7.54	6.86	6.23	39.1	37.8	10.12	9.96	101	83	14.4	2.7	448	440
July 18	20.15	7.62	7.25	6.26	37.7	47.4	9.60	9.51	103	81	5.8	5.9	316	327
Aug. 23	21.12	7.66	7.25	6.27	40.9	37.2	8.63	8.98	97	73	9.0	2.3	384	388
Sept. 19	19.09	7.67	7.19	6.25	39.5	36.9	9.36	8.99	100	75	1.3	2.9	324	334
Oct. 18	14.92	7.68	6.90	6.26	38.5	36.5	9.44	8.64	93	72	5.8	5.2	363	356

Table 7. Mean Secchi disk readings (m) at Lake Ozette Stations 1-4, September 1993-October 1994.

Date	Station			
	1	2	3	4
Sept. 9, 1993	4.3	NA	3.7	5.3
Nov. 9, 1993	6.5	NA	NA	5.0
Dec. 15, 1993	5.1	NA	NA	NA
Feb. 1, 1994	4.5	5.0	NA	NA
May 11, 1994	NA	NA	4.5	NA
June 15, 1994	5.0	NA	NA	NA
July 18, 1994	NA	NA	NA	4.5
Aug. 23, 1994	5.3	NA	NA	NA
Sept. 19, 1994	NA	NA	NA	5.9
Oct. 18, 1994	NA	5.9	NA	NA

Table 8. Concentrations of nutrients in water samples collected from Lake Ozette, **August 29-30, 1993**. Samples collected from the surface, 18 m, and near the bottom in mg/L. Dissolved PO_4-P values equal to 0.001 were below the detection level of the lab instruments.

Station Number	Depth (m)	Total Kjeldahl Nitrogen	Dissolved Total Phosphorus	Dissoloved PO_4-P	Nitrate NO_3-N+NO_2-N	NH_3-N	pH	Alkal HCO_3-C	Conductivity (umho)	Dissolved Solids	Suspended Sediment
	1	.11	.005	.001	.043	.008	7.2	2.21	41.2	30	1.05
1	18	.10	.008	.001	.167	.005	6.7	1.95	43.4	32	0.57
	22	.10	.009	.003	.166	.006	6.7	1.97	43.0	34	0.67
	1	.10	.005	.001	.042	.010	7.2	2.21	43.0	34	1.44
2	18	.09	.100	.001	.167	.006	6.8	1.97	43.0	37	0.67
	53	.10	.009	.002	.169	.008	6.7	2.00	43.0	37	0.48
	1	.10	.005	.001	.044	.007	7.2	2.19	43.0	34	1.25
3	18	.09	.007	.001	.166	.007	6.8	1.97	41.2	37	0.57
	64	.10	.011	.003	.172	.007	6.7	2.02	43.0	37	0.38
	1	.12	.009	.003	.043	.010	7.3	2.21	43.0	37	5.97
4	18	.10	.006	.001	.168	.007	6.8	1.95	42.5	36	0.47
	62	.10	.009	.003	.170	.005	6.7	2.00	42.5	37	0.58

Table 9. Concentrations of nutrients in water samples collected from Lake Ozette, **January 18, 1994**. Samples collected from the surface, 18 m, and near the bottom in mg/L. Dissolved PO_4-P values equal to 0.001 were below the detection level of the lab instruments.

Station Number	Depth (m)	Total Kjeldahl Nitrogen	Dissolved Total Phosphorus	Dissoloved PO_4-P	Nitrate NO_3-N+NO_2-N	NH_3-N	pH	Alkal HCO_3-C	Conductivity (umho)	Dissolved Solids	Suspended Sediment
	1	.10	.004	.002	.167	.006	7.0	2.05	42.7	34	.95
1	18	.10	.004	.002	.163	.004	7.0	2.05	41.6	34	.75
	22	.10	.005	.002	.163	.011	7.0	2.05	41.6	32	.96
	1	.09	.004	.002	.166	.005	7.0	2.12	42.7	30	.66
2	18	.10	.005	.002	.166	.003	7.0	2.07	42.7	30	.67
	53	.09	.004	.002	.165	.004	7.0	2.07	41.6	29	.66
	1	.12	.008	.003	.164	.005	7.0	2.07	43.2	31	.47
3	18	.10	.004	.002	.164	.003	7.0	2.07	43.2	34	.76
	64	.10	.005	.002	.166	.002	7.0	2.07	42.7	38	.57
	1	.10	.006	.002	.165	.003	7.0	2.10	42.7	38	.47
4	18	.10	.005	.002	.167	.003	7.0	2.07	43.2	37	.48
	62	.10	.004	.002	.168	.004	6.9	2.07	41.2	36	.67

Table 10. Concentrations of nutrients in water samples collected from Lake Ozette, **May23, 1994**. Samples collected from the surface, 18 m, and near the bottom in mg/L. Dissolved PO_4-P values equal to 0.001 were below the detection level of the lab instruments.

Station Number	Depth (m)	Total Kjeldahl Nitrogen	Dissolved Total Phosphorus	Dissoloved PO_4-P	Nitrate NO_3-N+NO_2-N	NH_3-N	pH	Alkal HCO_3-C	Conductivity (umho)	Dissolved Solids	Suspended Sediment
1	1	.12	.005	.001	.108	.008	7.1	2.06	43.7	34	1.06
	18	.11	.007	.001	.107	.008	7.2	2.08	44.2	33	.48
	22	.11	.007	.001	.169	.007	6.9	1.96	44.2	37	.48
2	1	.12	.005	.001	.106	.005	7.2	2.08	44.2	33	.96
	18	.11	.006	.001	.171	.004	6.9	1.98	43.7	35	.38
	53	.10	.006	.001	.172	.005	6.9	1.96	44.2	34	.68
3	1	.12	.005	.001	.106	.007	7.2	2.06	44.2	33	1.16
	18	.10	.006	.001	.154	.004	7.1	2.03	44.2	32	.67
	64	.10	.006	.002	.174	.004	6.9	1.98	43.7	33	.68
4	1	.13	.008	.001	.111	.004	7.2	2.06	43.7	34	1.24
	18	.11	.007	.000	.154	.003	7.0	1.96	43.7	33	.68
	62	.11	.006	.001	.173	.003	6.9	1.96	43.7	39	.29

Table 11. Concentrations of nutrients in water samples collected from Lake Ozette, **July 18, 1994**. Samples collected from the surface, 18 m, and near the bottom in mg/L. Dissolved PO_4-P values equal to 0.001 were below the detection level of the lab instruments.

Station Number	Depth (m)	Total Kjeldahl Nitrogen	Dissolved Total Phosphorus	Dissoloved PO_4-P	Nitrate NO_3-N+NO_2-N	NH_3-N	pH	Alkal HCO_3-C	Conductivity (umho)	Dissolved Solids	Suspended Sediment
1	1	.11	.011	.002	.078	.007	7.2	2.25	42.1	32	.48
	18	.10	.010	.001	.172	.006	6.8	2.08	43.9	33	.38
	22	.11	.010	.002	.165	.011	6.8	2.08	43.9	32	.57
2	1	.11	.009	.001	.073	.011	7.3	2.27	45.3	33	.95
	18	.10	.009	.001	.174	.007	6.8	2.08	45.3	32	.57
	53	.13	.012	.001	.176	.012	6.8	2.05	43.9	33	
3	1	.10	.008	.000	.075	.008	7.3	2.25	43.9	32	1.07
	18	.10	.009	.001	.150	.014	6.8	2.08	43.4	35	.68
	64	.10	.011	.002	.177	.006	6.8	2.10	43.0	36	.56
4	1	.13	.008	.001	.074	.007	7.3	2.27	45.3	31	1.14
	18	.10	.012	.001	.181	.004	6.9	2.08	43.4	31	.48
	62	.10	.005	.002	.177	.007	6.8	2.08	43.4	31	.57

Table 12. Chemical composition in mg/L of water samples collected from Lake Ozette Stations 1 – 4 on August 29 – 30, 1993.

Station	**1**			**2**			**3**			**4**		
Depth (m)	**1**	**18**	**22**	**1**	**18**	**53**	**1**	**18**	**64**	**1**	**18**	**62**
Ca	3.101	2.805	2.769	2.864	2.798	2.813	2.916	2.802	3.061	3.054	2.836	2.913
Mg	0.956	0.930	0.916	0.943	0.931	0.936	0.960	0.927	0.936	0.972	0.926	0.947
K	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Na	3.810	3.762	3.715	3.777	3.769	3.755	3.802	3.702	3.711	4.107	3.751	3.775
S	0.961	0.975	0.971	0.964	1.040	0.992	0.990	0.982	0.958	1.047	0.995	1.000
P	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045
Si	0.821	1.693	1.698	0.852	1.660	1.689	0.847	1.616	1.762	0.946	1.677	1.739
Fe	0.065	0.129	0.215	0.126	0.111	0.142	0.130	0.112	0.335	0.172	0.147	0.256
Mn	<0.002	0.006	0.007	<0.001	<0.003	0.004	<0.001	0.004	0.010	<0.002	<0.003	0.010
Zn	0.217	0.015	0.024	0.019	0.097	0.022	0.073	0.169	0.108	0.071	0.026	0.026
Al	<0.035	<0.049	<0.055	<0.025	<0.045	<0.053	<0.029	<0.058	<0.044	<0.026	<0.035	<0.030
B	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cu	0.031	<0.008	<0.013	<0.011	<0.008	<0.009	0.028	0.047	0.026	0.021	0.021	<0.013
Cd	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cr	<0.004	<0.004	<0.010	<0.006	<0.004	<0.004	0.023	<0.006	<0.010	<0.008	<0.014	<0.006
Ni	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.007	<0.006
As	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150
Sb	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.043	<0.042	<0.032	<0.036	<0.040	<0.025
Pb	<0.025	<0.025	<0.025	<0.026	<0.025	<0.025	<0.045	<0.058	<0.025	<0.030	<0.025	<0.038
Mo	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Ti	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Sn	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sr	0.023	0.022	0.022	0.023	0.022	0.022	0.023	0.022	0.023	0.023	0.022	0.023

Less than symbol "<" = \below level of detection.

Table 13. Chemical composition in mg/L of water samples collected from Lake Ozette stations 1 – 4 on January 18 1994.

Station	**1**			**2**			**3**			**4**		
Depth (m)	**1**	**18**	**22**	**1**	**18**	**53**	**1**	**18**	**64**	**1**	**18**	**62**
Ca	2.968	2.818	2.793	2.789	2.827	2.837	2.831	2.828	2.824	2.819	2.819	2.854
Mg	0.965	0.933	0.913	0.922	0.931	0.944	0.934	0.935	0.921	0.924	0.928	0.937
K	<0.050	<0.070	<0.070	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Na	3.566	3.511	3.532	3.532	3.520	3.559	3.559	3.553	3.480	3.545	3.470	3.581
S	1.006	0.982	1.011	0.982	0.999	1.001	0.984	0.995	0.999	0.993	0.964	1.025
P	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045
Si	0.926	1.228	1.253	1.211	1.341	1.377	1.361	1.282	1.311	1.388	1.297	1.390
Fe	0.162	0.122	0.197	0.165	0.218	0.192	0.164	0.207	0.250	0.300	0.199	0.230
Mn	0.005	0.005	0.005	0.005	0.005	0.004	0.005	0.004	0.004	0.007	0.004	0.007
Zn	0.119	0.046	0.030	0.026	0.067	0.090	0.023	0.054	0.186	0.046	0.034	0.033
Al	0.189	<0.127	<0.076	<0.106	<0.119	<0.116	<0.087	0.152	<0.126	<0.130	<0.122	<0.133
B	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Cu	0.034	0.020	0.024	0.024	0.037	0.024	0.023	0.039	0.074	0.037	0.035	0.033
Cd	<0.008	<0.006	<0.006	<0.006	<0.008	<0.009	<0.008	<0.010	<0.009	<0.009	<0.010	<0.009
Cr	<0.015	<0.013	0.019	<0.017	0.023	<0.017	0.042	0.025	0.030	0.030	0.025	0.021
Ni	<0.021	<0.017	<0.015	<0.010	<0.018	0.042	<0.016	<0.012	<0.020	<0.015	<0.014	<0.017
As	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150
Sb	<0.025	<0.032	<0.028	<0.028	<0.031	<0.043	<0.051	<0.051	<0.025	<0.053	<0.035	<0.025
Pb	<0.052	<0.025	<0.040	<0.030	<0.040	<0.047	<0.025	<0.052	<0.061	<0.027	<0.035	<0.046
Mo	<0.004	<0.004	<0.004	<0.005	<0.004	<0.006	<0.006	<0.004	<0.004	<0.004	<0.005	<0.006
Ti	<0.004	<0.005	<0.004	<0.005	<0.005	<0.006	<0.004	<0.005	<0.008	<0.005	<0.005	<0.006
Sn	<0.015	<0.017	<0.012	<0.010	<0.010	<0.010	<0.012	<0.010	<0.011	<0.017	<0.016	<0.016
Sr	0.024	0.024	0.023	0.023	0.024	0.024	0.024	0.024	0.023	0.024	0.024	0.024

Less than symbol "<" = \below level of detection.

Table 14. Chemical composition in mg/L of water samples collected from Lake Ozette Stations 1 – 4 on May 23, 1994.

Station	1			2			3			4		
Depth (m)	1	18	22	1	18	53	1	18	64	1	18	62
Ca	2.834	2.823	2.842	2.797	2.787	2.817	2.796	2.848	2.803	2.828	2.847	2.813
Mg	0.931	0.950	0.954	0.954	0.935	0.960	0.929	0.959	0.943	0.865	0.870	0.867
K	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Na	3.430	3.479	3.504	3.452	3.464	3.480	3.494	3.554	3.532	3.465	3.477	3.453
S	0.967	1.016	1.025	0.961	0.987	0.998	0.976	1.014	0.997	0.970	0.995	0.964
P	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045
Si	1.318	1.533	1.558	1.351	1.438	1.520	1.367	1.445	1.443	1.420	1.415	1.567
Fe	0.132	0.271	0.202	0.158	0.103	0.123	0.171	0.182	0.182	0.188	0.079	0.230
Mn	<0.002	0.005	0.006	<0.003	0.004	0.004	<0.003	0.004	0.004	<0.003	<0.003	0.009
Zn	0.188	0.231	0.186	0.197	0.132	0.215	0.091	0.071	0.073	0.053	0.050	0.094
Al	<0.120	<0.130	<0.123	<0.110	0.142	<0.127	<0.110	<0.134	0.142	<0.058	<0.054	<0.066
B	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.009	<0.013	<0.011
Cu	0.026	0.065	0.027	0.034	0.024	0.018	0.028	0.027	0.026	0.019	<0.011	0.024
Cd	<0.008	<0.008	<0.008	<0.011	<0.006	<0.011	<0.010	<0.010	<0.009	<0.002	<0.002	<0.002
Cr	<0.017	0.028	0.023	0.023	<0.008	<0.009	0.025	0.021	0.022	0.020	<0.014	0.019
Ni	<0.021	<0.020	<0.025	<0.018	<0.020	<0.031	<0.023	<0.023	<0.022	<0.006	<0.006	<0.006
As	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150
Sb	<0.025	<0.029	<0.047	<0.028	<0.037	<0.034	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Pb	<0.025	<0.067	<0.050	<0.055	<0.025	<0.033	<0.046	<0.050	<0.043	<0.025	<0.025	<0.025
Mo	<0.004	<0.006	<0.004	<0.007	<0.004	<0.004	<0.004	<0.007	<0.005	<0.004	<0.004	<0.004
Ti	<0.005	<0.006	<0.005	<0.005	<0.005	<0.005	<0.005	<0.004	<0.005	<0.004	<0.004	<0.004
Sn	<0.010	<0.013	<0.012	<0.012	<0.017	<0.012	<0.028	<0.012	<0.022	<0.010	<0.010	<0.017
Sr	0.023	0.024	0.024	0.023	0.023	0.023	0.024	0.024	0.024	0.023	0.023	0.023

Less than symbol “<” = below level of detection.

Table 15. Chemical composition in mg/L of water samples collected from Lake Ozette Stations 1 – 4 on July 18, 1994.

Station	1			2			3			4		
Depth (m)	**1**	**18**	**22**	**1**	**18**	**53**	**1**	**18**	**64**	**1**	**18**	**62**
Ca	2.943	2.885	2.900	2.902	2.834	2.904	2.967	2.917	2.990	2.940	2.874	2.888
Mg	0.908	0.910	0.910	0.884	0.880	0.877	0.918	0.911	0.968	0.913	0.883	0.893
K	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Na	3.518	3.391	3.407	3.450	3.380	3.508	3.484	3.411	3.560	3.451	3.479	3.478
S	0.985	1.000	1.010	0.970	0.974	0.994	0.995	1.024	1.055	0.987	0.988	0.992
P	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045	<0.045
Si	1.386	1.501	1.568	1.263	1.555	1.603	1.295	1.535	1.629	1.301	1.613	1.603
Fe	0.116	0.207	0.340	0.185	0.175	0.110	0.136	0.070	0.145	0.064	0.228	0.172
Mn	<0.002	0.005	0.006	<0.003	<0.003	0.004	<0.002	<0.003	0.005	<0.002	0.004	0.005
Zn	0.279	0.289	0.278	0.112	0.128	0.087	0.254	0.268	0.565	0.253	0.271	0.220
Al	<0.049	<0.073	<0.064	<0.047	<0.068	<0.045	<0.051	<0.065	<0.097	<0.049	<0.070	<0.068
B	0.024	<0.008	<0.008	<0.005	<0.005	<0.005	<0.012	<0.010	0.023	<0.017	<0.022	<0.012
Cu	0.026	0.049	0.044	0.023	0.024	<0.08	0.028	0.016	<0.014	0.021	0.052	0.031
Cd	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cr	<0.011	0.020	0.026	<0.015	<0.014	<0.008	<0.016	<0.004	<0.005	<0.009	0.022	0.037
Ni	<0.006	<0.006	<0.009	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
As	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150	<0.150
Sb	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.029	<0.025	<0.025	<0.025	<0.025
Pb	<0.035	<0.032	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Mo	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Ti	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Sn	<0.010	<0.010	<0.013	<0.012	<0.010	<0.010	<0.010	<0.010	<0.010	<0.012	<0.010	<0.010
Sr	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023

Less than symbol “<” = below level of detection.

Table 16. Concentrations of chlorophyll at 0-20 and 0-5 m collected from Lake Ozette sampling Stations 1,2, and 4, 1994.

Date	Station	Chlorophyll			
		0-20 m.		0-5 m.	
		Mg/m^2	Mg/m^3	Mg/m^2	Mg/m^3
April 6	2	11.5	0.6	6.0	1.2
May 24	1	10.2	0.5	3.1	0.6
May 24	4	7.6	0.4	5.4	1.1
July 19	1	13.7	0.7	6.3	1.3
July 19	2	11.9	0.6	6.6	1.3

Table 17. Mean monthly densities (number/m^3) of zooplankton taxa in 0-30 and 0-5 m vertical tows, Lake Ozette, 1994. In addition to these species, small numbers of the rotifers *Trichotria sp., Trichocerca sp.,* and *Collotheca pelagica* were identified in our samples.

Species	Month	Density (#/m^3)	Density (#/m^3)
Cladocera			
Daphnia rosea	February	15.3	44.6
	May	30.2	631.5
Bosmina	February	17.5	66.9
	May	121.3	879.0
	July	10.6	
Holopedium gibberum	February		51.0
	May	34.4	226.9
Daphnia longiremis	February	17.0	
	May	63.7	220.3
	July	10.6	
Sida crystallina	May	36.7	160.4
	July	102.9	921.0
Leptodora kindtii	May	8.5	
Calanoid Copepod			
Diaptomus oregonensis	February	185.8	180.4
	May	16.0	433.2
	July	21.2	422.7
Cyclopoid Copepod			
Cyclops biscuspidatus	February	57.1	203.7
	May	391.1	1845.1
	July	920.7	1283.6
Rotifera			
Keratella cochlearis	February	63.2	
	May	451.1	
	July	1903.3	
Synchaeta sp1.	February	46.9	
	May	29.7	
Filinia sp.	February	10.6	
Polyarthra major	February	18.4	
	May	700.3	
	July	1272.2	
Synchaeta sp2.	February	6.4	
	May	132.6	
	July	87.5	
Conchilus unicornus	February	62.4	
	May	1159.4	
	July	1726.0	
Ploesoma sp.	February	17.0	
	May	76.2	
	July	156.0	
Keratella taurocephala	February	9.3	
Kellicottia longispina	May	51.6	
Lecane sp.	May	26.7	
Monostyla sp1.	May	43.5	
Platyias	February	8.5	
Monostyla sp2.	February	8.5	
Notholca acuminata	February	8.5	

Table 18. Plant taxa identified in vegetation plots at Lake Ozette.

Grasses	
Phalaris arundinacea	Reed canarygrass
Poaceae sp.	Grasses
Herbaceous Plants	
Equisetum arvense	Horsetail
Gentiana douglasiane	Swamp gentian
Potentilla sp.	Cinquefoil
Viola sp.	Violets
Mentha sp.	Mints
Polygonum sp.	Polygonum
Blechnum spicant	
Aster sp.	Asters
Rosa sp.	Rose hip
Galium sp.	Bedstraw
Ranunculus sp.	Buttercup
Rushes	
Juncus sp.	Rushes
Scirpus sp.	Bulrush
Eleocharis sp.	Spike-rushes
Sedges	
Carex sp.	Sedges
Shrubs	
Myrica gale	Sweet gale
Salix sp.	Willows
Spirea sp.	Spirea
Aquatics	
Utricularia sp.	Bladderwort
Sparganium emersum	Simplestem bur-reed
Potamogeton sp.	Pondweeds
Nuphar luteum	Yellow pond-lily

Table 19. Range of values for water quality variables collected in the tributaries and outlet to Lake Ozette, 1993-94. Only includes data collected between December 1993 - November 1994 with the Hydrolab multi-parameter probe. Discharges are not representative of peak flows as it was not possible to wade these streams at high flows, especially in Crooked Creek and Big and Ozette Rivers.

Stream	Temperature (C)	pH	Dissolved Oxygen (mg/l)	Specific Conductivity (uS/cm)	Turbidity (NTU)	Redox	Discharge (cfs)
Ozette R.	6.70-19.02	6.40-7.42	8.07-11.84	31.30-42.97	0.35-14.15	320-483	14.34-105.38
Coal Cr.	5.66-14.79	5.74-6.82	5.56-11.36	27.30-76.23	1.45-48.27	336-456	NA
Umbrella Cr.	2.74-16.0	6.37-7.40	8.26-12.26	24.20-100.50	0.30-161.00	307-459	0.73-58.54
Big R.	3.48-16.77	6.01-7.10	7.25-11.58	22.60-62.30	0.70-185.00	324-464	1.63-36.55
Crooked Cr.	2.58-16.06	5.71-7.20	7.46-11.99	17.90-53.20	0.00-21.60	327-476	0.45-6.17
Siwash Cr.	3.67-15.08	6.18-7.30	9.36-11.37	25.10-73.00	0.00-22.10	303-477	0.43-19.82
South Cr.	3.21-15.68	6.03-7.01	7.90-12.66	26.70-81.80	3.00-13.67	330-500	0.45-26.31

Table 20. Monthly water quality values for the **Ozette River**, 1993-94. Data collected on January 5, 1994 and prior to December 16, 1993 measured with various hand held instruments; all other information measured with a Hydrolab multi-parameter instrument. Measurements made on December 11, 1993, March 2, and November 30, 1994 collected during storm events.

Date	Temperature (C)	pH	Specific Conductivity (uS/cm)	Dissolved Oxygen (mg/l)	Turbidity (NTU)	Redox	Discharge (cfs)
7/25/93	13	--	39.0	--	0.9	--	105.38
8/17/93	19	--	39.2	--	1.2	--	43.80
9/24/93	17	--	47.4	9.2	1.0	--	14.34
11/2/93	12	--	37.2	11.8	2.2	--	59.72
12/11/93	8	--	37.0	--	1.8	--	--
12/16/93	8.13	7.06	34.10	10.05	--	373	--
1/5/94	8.00	--	35.80	--	--	--	--
2/2/94	6.70	7.00	--	10.97	--	407	--
2/16/94	7.25	6.93	34.30	10.85	--	483	--
2/22/94	7.02	7.04	34.40	10.86	--	416	--
3/2/94	8.15	6.40	31.30	10.25	7.90	462	--
3/30/94	9.68	7.00	37.60	10.58	3.50	397	--
4/20/94	11.32	7.14	38.70	11.84	0.35	416	--
5/12/94	14.76	7.42	41.80	9.77	--	411	--
6/15/94	17.09	6.90	39.10	9.77	14.15	421	--
7/20/94	19.02	6.92	37.70	9.39	1.50	422	94.86
8/25/94	17.93	6.72	42.97	8.07	3.57	367	29.09
9/20/94	17.58	6.89	39.80	9.27	2.33	320	49.77
10/19/94	13.96	6.98	38.40	8.75	3.93	342	26.68
11/16/94	9.89	6.71	37.23	10.09	1.67	355	--
11/30/94	8.51	6.72	39.27	10.60	0.87	385	--

Table 21. Monthly water quality values for **Coal Creek**, 1993-94. All data collected with a Hydrolab multi-parameter instrument. Measurements made on March 2 and November 30, 1994 collected during storm events.

Date	Temperature (C)	pH	Specific Conductivity (uS/cm)	Dissolved Oxygen (mg/l)	Turbidity (NTU)	Redox
12/16/93	7.04	6.82	54.00	11.12	--	377
2/16/94	6.97	6.28	37.20	10.57	--	452
2/23/94	5.66	6.62	40.50	11.36	--	423
3/2/94	8.67	5.90	27.30	10.09	23.80	456
3/30/94	9.12	6.65	51.90	9.75	4.15	396
4/20/94	10.69	6.77	61.20	11.00	1.45	406
5/12/94	11.37	6.75	70.00	8.24	--	387
6/15/94	11.16	6.28	55.60	10.68	18.20	376
7/18/94	14.79	6.26	62.50	7.51	6.10	385
8/25/94	13.74	6.57	62.83	5.71	10.73	380
9/20/94	14.12	6.57	76.23	8.96	4.10	342
10/19/94	8.88	6.65	70.33	6.56	2.53	336
11/16/94	7.39	6.31	54.83	10.99	5.60	367
11/30/94	8.10	5.74	44.00	10.91	48.27	386

Table 22. Monthly water quality values for **Umbrella Creek**, 1993-94. Data collected on January 5, 1994 and prior to December 15, 1993 measured with various hand held instruments; all other information measured with a Hydrolab multi-parameter instrument. Measurements made on December 11, 1993, March 2, and November 30, 1994 collected during storm events.

Date	Temperature (C)	pH	Specific Conductivity (uS/cm)	Dissolved Oxygen (mg/l)	Turbidity (NTU)	Redox	Discharge (cfs)
7/21/93	14	--	85.0	--	1.4	--	3.59
8/20/93	16	--	96.1	--	1.5	--	3.37
9/24/93	13	--	39.4	8.86	1.9	--	0.73
11/2/93	48	--	79.4	9.6	1.5	--	5.59
12/11/93	7	--	39.4	--	19.0	--	--
12/16/93	6.56	7.06	42.50	10.66	--	345	58.54
1/5/94	8.00	7.40	37.80	--	5.40	--	--
2/2/94	2.74	7.19	49.80	12.26	15.80	350	17.18
2/16/94	6.75	6.75	31.20	11.13	20.70	455	--
2/22/94	5.22	6.87	34.70	11.67	20.10	392	--
3/2/94	8.72	6.37	24.20	10.05	51.50	459	--
3/30/94	9.11	7.00	55.70	10.28	5.55	389	17.45
4/20/94	12.11	7.18	58.30	11.17	0.36	391	--
5/12/94	11.01	7.16	83.80	9.24	55.40	345	--
6/16/94	11.91	6.76	50.00	10.53	5.55	372	--
7/20/94	15.88	6.82	81.60	8.73	0.30	351	3.03
8/25/94	14.60	6.97	100.50	8.26	2.92	339	1.46
9/20/94	14.82	7.06	78.60	9.74	4.15	319	7.73
10/19/94	8.87	7.14	90.53	9.02	0.80	307	3.22
11/16/94	7.25	6.62	44.53	11.50	6.83	350	--
11/30/94	7.81	6.19	35.00	11.42	161.00	381	--

Table 23. Water quality values for **Big River**, 1993-94. Data collected on January 5, 1994 and prior to December 15, 1993 measured with hand held instruments; all other information measured with a Hydrolab multi-parameter instrument. Measurements made on December 11, 1993, March 2, and November 30, 1994 collected during storm events.

Date	Temperature (C)	pH	Specific Conductivity (uS/cm)	Dissolved Oxygen (mg/l)	Turbidity (NTU)	Redox	Discharge (cfs)
7/21/93	14	--	58.0	--	2.2	--	6.43
8/20/93	16	--	62.1	--	1.9	--	4.88
9/24/93	11	--	70.0	9.82	2.0	--	1.63
11/2/93	47	--	61.8	8.40	2.1	--	10.56
12/11/93	8	--	42.6	--	52	--	--
12/16/93	7.07	6.97	41.90	9.73	--	362	--
1/5/94	8.00	7.10	39.00	--	--	--	--
2/2/94	3.48	7.04	45.50	11.58	--	373	--
2/16/94	6.91	6.60	30.50	10.51	--	464	--
2/22/94	5.35	6.64	34.20	11.15	--	404	--
3/2/94	8.90	6.08	22.60	9.05	57.30	427	36.55
3/30/94	9.26	6.76	48.30	10.04	5.70	377	--
4/20/94	11.00	7.01	49.90	11.20	0.70	387	--
5/12/94	12.00	6.86	61.40	8.67	--	363	--
6/16/94	10.81	6.48	44.60	10.28	19.70	359	--
7/20/94	16.77	6.52	57.10	8.44	3.20	399	7.28
8/25/94	14.39	6.72	62.30	8.15	7.07	358	3.46
9/20/94	14.67	6.74	60.83	9.08	5.63	328	--
10/19/94	8.93	6.86	59.20	7.25	2.10	324	7.27
11/16/94	7.11	6.29	43.30	10.77	8.87	332	--
11/30/94	8.14	6.01	34.40	10.00	185.00	386	--

Table 24. Monthly water quality values for **Crooked Creek**, 1993-94. Data collected on January 5, 1994 and prior to December 15, 1993 measured with various hand held instruments; all other information measured with a Hydrolab multi-parameter instrument. Measurements made on December 11, 1993, March 2, and November 30, 1994 collected during storm events.

Date	Temperature (C)	pH	Specific Conductivity (uS/cm)	Dissolved Oxygen (mg/l)	Turbidity (NTU)	Redox	Discharge (cfs)
7/20/93	14	--	43.0	--	2.6	--	2.54
8/17/93	15	--	46.4	--	3.3	--	1.74
9/24/93	13	--	39.4	7.6	3.7	--	0.45
11/9/93	8	--	53.2	11.2	2.6	--	4.39
12/11/93	7	--	32.0	--	41.0	--	--
1/5/94	8.00	7.20	34.20	--	--	--	--
2/2/94	2.58	6.79	33.00	11.99	--	387	--
2/16/94	6.83	6.38	24.50	11.35	--	454	--
2/22/94	5.20	6.61	30.40	11.31	--	476	--
3/2/94	8.83	5.76	17.90	10.21	21.60	473	--
3/30/94	9.26	6.45	36.40	10.09	7.30	391	--
4/20/94	11.18	7.08	38.60	11.57	4.20	396	--
5/12/94	12.70	6.74	45.40	8.51	--	406	--
6/16/94	10.72	6.31	34.30	9.88	0.00	378	--
7/19/94	15.53	6.66	43.90	8.44	5.77	327	3.26
8/23/94	16.06	6.37	49.20	7.46	0.00	356	2.37
9/19/94	15.86	6.43	48.60	8.76	3.50	337	6.17
10/18/94	8.85	6.62	47.80	9.49	6.03	367	2.41
11/16/94	7.43	6.13	34.07	11.16	5.20	339	--
11/30/94	8.15	5.71	31.40	11.30	19.87	394	--

Table 25. Monthly water quality values for **Siwash Creek**, 1993-94. Data collected on January 5, 1994 and prior to December 15, 1993 measured with various hand held instruments; all other information measured with a Hydrolab multi-parameter instrument. Measurements made on December 11, 1993 and March 2, 1994 collected during storm events.

Date	Temperature (C)	pH	Specific Conductivity (uS/cm)	Dissolved Oxygen (mg/l)	Turbidity (NTU)	Redox	Discharge (cfs)
7/22/93	13	--	63.0	--	1.7	--	2.06
8/16/93	15	--	66.9	--	2.3	--	0.91
9/24/93	12	--	63.6	9.44	6.5	--	0.43
11/10/93	7	--	--	10.90	4.9	--	1.23
12/11/93	9	--	30.8	--	22.0	--	--
12/15/93	7.82	6.60	37.20	10.44	--	--	19.82
1/5/94	8.00	7.30	34.00	--	--	--	--
2/1/94	3.67	7.17	45.60	11.32	--	361	6.29
2/22/94	5.90	6.60	30.90	11.05	--	477	--
3/2/94	9.02	6.18	25.10	10.04	2.70	424	--
3/30/94	9.66	6.50	52.90	10.21	6.60	398	6.93
4/20/94	9.79	7.13	53.80	11.37	0.80	385	--
5/12/94	12.02	7.05	66.80	9.50	--	386	--
6/15/94	11.63	6.61	44.02	10.24	2.45	439	13.85
7/19/94	14.12	6.97	65.30	9.51	0.00	308	0.55
8/23/94	15.08	6.88	73.00	9.62	12.10	322	0.81
9/19/94	13.97	6.91	70.80	9.36	4.10	303	1.32
10/18/94	8.65	7.05	70.60	10.07	6.30	338	0.85

Table 26. Monthly water quality values for **South Creek**, 1993-94. Data collected on January 5, 1994 and prior to December 15, 1993 measured with various hand held instruments; all other information measured with a Hydrolab multi-parameter instrument. Measurements made on March 2, 1994 collected during a storm event.

Date	Mean Daily Temperature (C)	pH	Specific Conductivity (uS/cm)	Dissolved Oxygen (mg/l)	Turbidity (NTU)	Redox	Discharge (cfs)
7/22/93	14	--	65.0	--	3.5	--	2.11
8/16/93	14	--	77.7	--	3.5	--	0.84
9/21/93	12	--	--	7.9	4.8	--	0.45
11/10/93	7	--	81.8	10.8	3.7	--	0.95
12/15/93	7.97	6.70	37.20	9.70	--	395	26.31
1/5/94	8.00	7.00	35.20	--	4.40	--	--
2/1/94	3.21	6.96	45.00	12.66	--	413	6.90
2/22/94	6.03	6.66	32.10	10.83	--	500	--
3/2/94	9.30	6.03	26.70	8.65	6.20	436	--
3/30/94	8.84	6.93	50.40	10.41	8.40	457	9.40
4/21/94	10.47	6.96	53.10	10.09	3.00	491	--
5/11/94	12.74	6.91	68.10	8.21	--	430	--
6/15/94	11.56	6.23	44.60	10.08	6.90	418	11.22
7/19/94	15.61	6.83	65.30	8.84	4.40	336	1.48
8/23/94	15.68	6.67	80.60	8.23	13.67	366	0.91
9/19/94	14.80	6.85	73.60	8.58	5.80	330	1.24
10/18/94	8.77	7.01	77.70	9.29	8.66	337	0.94

Table 27. Fish captured by electrofishing in four reaches of Siwash Creek, July 25, 1994.

Reach/River Kilometer	Species	Number Captured	Mean Fork Length (mm)	Effort
1/0.2	Sculpin	62	--	30 minutes
	Cutthroat	4	111	
	Coho	1	72	
	Lamprey spp.	2	--	
2/0.5	Sculpin	68		45 minutes
	Cutthroat	6	83	
	Coho	1	--	
	Lamprey spp.	1	--	
	Trout Fry	1	--	
3/2.4	Sculpin	124	--	20 minutes
	Cutthroat	22	67	
	Coho	1	67	
	Trout Fry	8	--	
4/3.2	Cutthroat	2	90	40 minutes
	Trout Fry	1	--	

Table 28. Fish captured by electrofishing in four reaches of Big River, July 26, 1994.

Reach/River Kilometer	Species	Number Captured	Mean Fork Length (mm)	Effort
1/1.2	Sculpin	25	--	30 minutes
2/5.6	Sculpin	94	--	45 minutes
	Coho	4	69	
	Steelhead/ Rainbow	18	75	
	Trout Fry	9	--	
3/7.2	Sculpin	62	--	20 minutes
	Coho	1	80	
	Steelhead/ Rainbow	12	67	
	Trout Fry	4	--	
4/10.5	Sculpin	54	--	40 minutes
	Coho	2	66	
	Steelhead/ Rainbow	6	67	

Table 29. Annual total precipitation, minimum, maximum, range, and mean monthly lake levels recorded at the Lake Ozette Ranger Station, 1981-94 and 1998-99.

Water Year	Precipitation (m)	Lake Level (m)		
		Minimum	Maximum	Range
1981-82	2.30	9.60	12.44	2.84
1982-83	2.65	9.84	11.92	2.08
1983-84	2.50	9.67	12.22	2.55
1984-85	1.82	9.61	11.61	2.00
1985-86	2.03	9.66	11.64	1.98
1986-87	1.86	9.57	11.30	1.73
1987-88	1.87	9.52	11.29	1.77
1988-89	1.93	9.64	11.77	2.13
1989-90	2.20	9.69	12.04	2.35
1990-91	2.53	9.80	12.34	2.54
1991-92	1.72	9.63	12.25	2.62
1992-93	1.82	9.66	11.00	1.34
1993-94	1.55	9.72	12.10	2.38
1998-99	2.79	9.63	12.34	2.71

Mean Monthly Lake Level (m)	
October	9.98
November	10.00
December	10.43
January	10.34
February	10.38
March	10.22
April	9.84
May	9.60
June	9.41
July	9.25
August	9.10
September	9.08

Table 30. Stand age, road density and road crossings in the Ozette watershed.

		Umbrella Creek	Big River	Crooked Creek	Siwash Creek	South Creek
Watershed Area (km^2)		30.4	59.4	29.9	7.6	8.1
	Age/years			%		
	0-10	32.72	27.67	52.98	74.11	46.27
	11-20	46.35	21.58	7.03	0.56	37.36
	21-40	14.39	34.88	8.99	6.83	0
	41-80	4.18	13.80	12.64	2.05	0.58
	80+	0.07	0.62	16.70	16.27	15.78
	Wetlands	1.05	0.24	0	0	0
	Unknown	1.24	1.21	1.64	0.16	0.03
Road Density (km/km^2)		3.05	2.36	2.03	2.50	3.09
Stream Crossings		83	150	48	22	42

Appendix A

Calibration Procedures for the Hydrolab Datasonde 3

Temperature: The temperature sensor is factory-set and requires no calibration. All units are recorded in degrees Celsius.

Specific Conductance: Specific conductivity was measured using a freshwater cell block installed upon arrival of the instrument. A 103.5 microsiemens/cm VWR standard was used to calibrate this variable. The following variables were selected from the menu on the Surveyor 3: C=specific conductance; U=microsiemens/cm (units); F=freshwater cell block; A=auto range which automatically selects the appropriate specific conductance measuring range; S=salinity; and T=temperature compensated as conductivity is highly dependent on temperature.

pH: pH was always calibrated with a "zero" buffer 7.00 +- 0.02 standard, followed by a "slope" buffer of 10.00 +- 0.02. The pH standards were made monthly from Hydrion Buffer Chemvelopes and Beckmann pH buffers (as of 8/1/94).

Redox: Though Redox rarely needs to be calibrated, it can be verified by dissolving a few grams of quinhydrone in 500 mL of 4.00 and 7.00 pH buffers.

Dissolved Oxygen: Dissolved oxygen (mg/L) was calibrated with the barometric pressure obtained from the U.S. Coast Guard in Port Angeles, WA. After removing the white DO guard sleeve from the sensor, distilled water was poured to just below the rubber gasket surrounding the membrane. The calibration cap was set upside down, and readings were allowed to stabilize for 5 minutes. Dissolved oxygen was selected from the calibration menu, and 760 mmHg was entered as the barometric pressure. A dissolved oxygen value in mg/L obtained from the appendix was then entered, based on the actual temperature of the water in the cup. Finally, the true barometric pressure (from U.S. Coast Guard) was entered into the percent saturation heading found in the variables menu. The following selections from the variables menu were used for all sample dates: S=standard membrane; and S=salinity compensated, which compensates for any influence from salinity.

Turbidity: Turbidity was calibrated with "turbidity free" water for a zero calculation. In addition, a 4000 NTU Hach Company Formazin was used to prepare various standards, all dependent on the relative turbidity of waters to be sampled. A standard was created by using the formula: Standard=Stock (4000 NTU)*Stock (volume)/(Stock (volume))+(Total (volume)). A 90 NTU standard, made from 489 mL of distilled water and 11.3 mL of 4000 NTU stock, was used for nearly all sample dates. While performing this calibration, it was imperative to eliminate any air bubbles present near the turbidity sensor. In addition, daily preparation of these standards was required as they often loose their potency. The turbidity sensor was operating in the R=ratio mode which uses two sensors as opposed to only one; and A=auto range where the unit selects the appropriate range from which it displays the reading. All readings use Nephelometric Turbidity Units (NTU).

Depth: Calibration was accomplished by zeroing the sensor just **above** the surface of water. All readings were recorded in feet.

Appendix B

Lake Ozette Vegetation Transect and Plot Descriptions

Transect A; Ozette River: This transect contained seven plots of distinctly different vegetation zones. The upper zone, nearest the fence post, is dominated by reed canary grass (Phalaris arundinacea) with hardhack (Spiraea douglasii/menziesii) occupying roughly 10% of the plot. The next distinct zone, down toward the shoreline, is primarily Spiraea with a few Sedges (Carex spp.) interspersed. The Spiraea abruptly changes to predominately Carex then filters into a mixture of Carex, Phalaris arundinacea (RCG), and Spiraea in descending orders of dominance. At approximately 26 meters from the fence post, Rushes (Juncas spp.) and Horsetail (Equisetum spp.) take over with scattered RCG. The aquatic zone starts at 31.2 meters where approximately half the plot is dominated by Bur-Reed (Sparganium sp.) with Equisetum spp. occupying 10% of the total area. The last plot (A7) extends 37 meters from the fence post and holds equal amounts of Marsh Pepper (Polygonum sp.), Pondweed (Potamogeton spp.), and Equisetum, each taking up roughly 10% of the area. Distance from fence post to shoreline = 29.3 m; distance from shoreline to outer edge of aquatic vegetation = 16.7 m; Total distance = 46.0 m.

Transect B; Cemetery Point: Transect B contained four plots with the upper zone dominated by Carex spp. and a few scattered Juncus, Spiraea, and Salix. Plot B2, a transition area, is again dominated by Carex, but with spiraea increasing to approx. 30% - 40% coverage while Juncas remained < 5%. Plot B3 is predominately Spiraea with Carex covering < 5% of the area. The lowest plot near the shoreline (B4) is mainly Juncus with Bulrush (Scirpus spp.) scattered over < 5% of the area. There was no visible aquatic vegetation. Total distance from fence post to shoreline = 25 m.

Transect C; South Creek: Plot C1 is dominated by Spiraea with traces of RCG and Salix. C2 has a relatively even mixture of Carex, RCG, and Spiraea with Carex covering slightly more area than the latter two. A trace of Salix and Scirpus are also present. Plot C3 is aquatic/terrestrial with Sparganium and Nuphar polysepalum occupying equal coverage (40% - 50%) with traces of Cinquefoil (Potentilla spp.), Spiraea, Mentha, and Salix. Plot C4 is aquatic/submergent with N. polysepalum dominating over S. emersum. and traces of Polygomum, Potamogeton, and Equisetum. Distance from fence post to shoreline = 11.6 m; distance from shoreline to aquatic edge = 7.4 m; total distance = 19.0 m.

Transect D; Siwash Creek: This transect has high species "richness" with many unidentifiable ground cover plants. Plot D1 consists mainly of Carex with Bedstraw (Galium spp.) scattered over roughly 15% of the area along with traces of Salix, Spiraea, and a few unidentifiable grasses. D2 again is dominated by Carex (25%-50%) with Spiraea and various grasses less abundant. Plot D3 contained mostly Spiraea and several grasses with Potentilla and Mentha found in trace amounts. D4 contains equal amounts of Carex and Juncus with less abundant amounts of Potentilla, Spiraea, and grasses. Total distance from fence post to shoreline = 15.7 m.

Transect E; Crooked Creek: Transect E facilitated five plots with the upper most (E1) supporting mainly Spiraea and a trace of Salix and Carex. Plot E2 is a transition area with Spiraea still dominating but with increased amounts of Juncas and Carex. E3 is predominately Juncas with Carex less abundant and Mentha occupying < 5% of the area. Plot E4 is aquatic with Sparganium covering just less than half the area and Equisetum covering < 1%. E5 is also aquatic with Potamogeton submergent and floating

over less than half the total area and a trace of Equisetum. Distance from fence post to shoreline = 14.0 m; distance from shoreline to aquatic edge = 8.6 m; total distance = 22.6 m.

Transect F; Big River: This transect was the longest and contained eight plots. F1 is dominated by Spiraea with Carex occupying < 5%. Plot F2 located 18.4 m from the fence post is again predominately Spiraea with Carex and RCG making its first appearance. F3 is a transition area containing equal amounts of Spiraea and Carex (26%-50%) with scattered amounts of RCG and Salix (< 5%). F4 is dominated by Carex with < 5% RCG and traces of Scirpus and Equisetum. F5 has equal amounts of Carex and N. polysepalum (26%-50%) with less abundant Bladderwort (Utricularia spp.). F6 is and aquatic zone located 47 m from the fence post with equal amounts of N. polysepalum and Utricularia. F7 is also aquatic located 84 m from the fence post and contains mainly N. polysepalum with less abundant Sparganium and Utricularia. F8 is dominated by N. polysepalum with < 5% Sparganium. Distance from fence post to shoreline = 45.0 m; distance form shoreline to aquatic edge 52.0 m; total distance = 97.0 m. It should be noted that there is a small section of Pondweed (Potamogeton) just beyond the aquatic edge that was inaccessible.

Transect G; Umbrella Creek: This transect contained six plots with G1 dominated by sweet gale. G2 is predominately RCG with < 10% Salix and sweet gale and a trace of Potentilla. Plot G3 has equal amounts (26%-50%) of RCG and sweet gale with Salix covering < 5% of the area. G4 was mainly covered by Juncas with less abundant Spike-Rush (Eleocharis spp.) and some Salix. G5 contains mainly Juncas with small amounts of Salix and Eleocharis. G6 is located near the shoreline and dominated by Eleocharis and Juncas. No aquatic vegetation was visible. Total distance from fence post to shoreline = 42.4 m.

Appendix C
Lake Ozette Vegetation Plots Results

Transect A: Near Ozette River outlet at north end of lake; left bank of river. Transect oriented 50° north, 29.3 m. from post to lake shore. Aquatic vegetation extends 16.7 m from shore.

	A1	A2	A3	A4	A5	A6
Distance from post	5.7 m.	12.8 m.	17.7 m.	23.3 m.	26.3 m.	31.2 m.
Grasses	85	Trace	Trace	25	1-5	0
Shrubs	10	75	4	5	0	0
Sedges	0	25	96	60	Trace	0
Herbs	Trace	0	Trace	1-5	60	0
Rushes	Trace	0	Trace	0	35	10
Aquatic	0	0	0	0	0	40

Transect B: Four plots near Cemetery Point. Transect oriented 100° north; total distance from fence post to shoreline is 24 m.

	B1	B2	B3	B4
Distance from post	1.3 m.	5.5 m.	10.5 m.	40.0 m.
Grasses	0	0	0	0
Shrubs	<1	30	96-99	0
Sedges	96-99	1-5	1-5	1-5
Herbs	Trace	0	Trace	Trace
Rushes	<1	65	0	96-99
Aquatic	0	0	0	0

Transect C: Four plots near South Creek. Transect oriented 270° north; distance from fence post to shoreline is 11.6 m; distance from shoreline to aquatic edge is 7.4 m; and total distance is 19.0 m.

	C1	C2	C3	C4
Distance from post	1.5 m.	5.3 m.	9.2 m.	13.6 m.
Grasses	1-5	25	80	0
Shrubs	96-99	6-25	<1	0
Sedges	0	26-50	0	0
Herbs	Trace	0	1-5	1-5
Rushes	0	Trace	0	0
Aquatic	0	0	0	75-96

Transect D: Four plots north of Siwash Creek. Transect oriented 250° north; the total distance from fence post to shoreline is 15.7 m.

	D1	D2	D3	D4
Distance from post	2.1 m.	5.9 m.	9.4 m.	12.5 m.
Grasses	Trace	6-25	6-25	1-5
Shrubs	<1	6-25	26-50	1-5
Sedges	25-50	25-50	0	25-50
Herbs	6-25	1-5	Trace	1-5
Rushes	0	0	0	25-50
Aquatic	0	0	0	0

Transect E: Five plots near Crooked Creek. Transect oriented 280° north; distance from fence post to shoreline is 14.0 m; distance from shoreline to the aquatic edge is 8.6 m and the total distance is 22.6 m.

	E1	E2	E3	E4	E5
Distance from post	2.7 m.	7.9 m.	11.3 m.	15.9 m.	20.6 m.
Grasses	0	0	0	0	0
Shrubs	96-99	25-50	Trace	0	0
Sedges	Trace	6-25	6-25	0	0
Herbs	0	Trace	1-5	<1	Trace
Rushes	0	6-25	76-95	0	0
Aquatic	0	0	0	26-50	25-50

Transect F: Eight plots near Big River. Transect oriented 65° north; distance from fence post to shoreline is 45.0 m; distance from the shoreline to aquatic edge is 52.0 m and total distance is 97 m.

	F1	F2	F3	F4	F5	F6	F7	F8
Distance from post	3.5 m.	18.4 m.	28.0 m.	31.6 m.	44.0 m.	47.0 m.	86.0 m.	95.0 m.
Grasses	0	1-5	1-5	1-5	0	0	0	0
Shrubs	96-99	76-95	26-50	0	0	0	0	0
Sedges	1-5	1-5	26-50	96-99	26-50	0	0	0
Herbs	0	0	0	Trace	0	0	0	0
Rushes	0	0	0	Trace	0	0	0	0
Aquatic	0	0	0	0	26-50	26-50	50-75	96-100

Transect G: Six plots near Umbrella Creek. Transect oriented 215° north and the total distance from fence post to shoreline is 42.4 m.

	G1	G2	G3	G4	G5	G6
Distance from post	1.5 m.	9.8 m.	18.8 m.	29.3 m.	34.7 m.	40.0
Grasses	0	50-75	26-50	0	0	0
Shrubs	96-99	1-5	26-50	1-5	6-25	0
Sedges	0	0	0	0	0	0
Herbs	T	T	0	T	0	0
Rushes	0	0	0	26-50	76-95	50-75
Aquatic	0	0	0	0	0	0

Appendix D
Temperature Data from Lake Ozette Tributaries

Appendix D, Table 1. Daily maximum and minimum water temperatures in **Big River** between August 25 - November 3, 1994. Sometime between June 16 and August 25, the thermograph probe was exposed to air. The unit was redeployed on August 25.

Date	Maximum	Minimum
Aug 25	15.90	13.50
Aug 26	16.00	14.40
Aug 27	16.00	14.10
Aug 28	16.10	15.20
Aug 29	16.30	15.00
Aug 30	16.10	14.80
Aug 31	15.90	15.00
Sep 01	15.20	14.10
Sep 02	14.50	13.20
Sep 03	14.00	13.60
Sep 04	14.60	13.60
Sep 05	14.10	12.60
Sep 06	14.60	13.20
Sep 07	14.70	14.10
Sep 08	14.70	14.30
Sep 09	14.40	13.20
Sep 10	13.60	12.90
Sep 11	13.80	12.90
Sep 12	13.60	12.80
Sep 13	13.30	12.90
Sep 14	13.60	13.20
Sep 15	14.10	13.30
Sep 16	14.50	13.40
Sep 17	14.60	14.10
Sep 18	14.90	14.20
Sep 19	14.80	14.00
Sep 20	15.20	14.30
Sep 21	15.10	14.30
Sep 22	15.00	13.70
Sep 23	14.30	13.80
Sep 24	14.20	13.70
Sep 25	14.30	13.70
Sep 26	13.70	12.80
Sep 27	13.40	12.40
Sep 28	13.40	12.40
Sep 29	14.00	13.20
Sep 30	14.40	13.80
Oct 01	1 4.30	13.40
Oct 02	13 .30	11.80
Oct 03	11.70	10.90
Oct 04	11.00	10.20
Oct 05	10.60	9.80
Oct 06	11.40	10.50

Date	Maximum	Minimum
Oct 07	11.20	10.10
Oct 08	10.50	9.70
Oct 09	10.70	10.00
Oct 10	10.70	10.20
Oct 11	10.40	9.20
Oct 12	9.60	8.70
Oct 13	9.00	8 .30
Oct 14	9.40	8.70
Oct 15	9.10	8.50
Oct 16	8.70	7.80
Oct 17	9.10	8.20
Oct 18	8.90	8.30
Oct 19	9.40	8.70
Oct 20	10.40	9.40
Oct 21	10.50	9.50
Oct 22	9.70	8.70
Oct 23	9.90	9.00
Oct 24	9.70	8.80
Oct 25	10.00	9.10
Oct 26	10.50	10.10
Oct 27	10.50	10.10
Oct 28	10.00	9.10
Oct 29	9.30	8.00
Oct 30	8.90	8.20
Oct 31	9.40	8.60
Nov 01	9.00	8.20
Nov 02	8.30	7.00
Nov 03	7.00	6.30

Appendix D, Table 2. Daily maximum and minimum water temperatures in **Crooked Creek** between June 16 - October 26, 1994.

Date	Maximum	Minimum
Jun 16	12.40	10.90
Jun 17	12.90	11.60
Jun 18	12.90	12.20
Jun 19	13.50	11.50
Jun 20	13.60	11.50
Jun 21	15.00	11.40
Jun 22	16.40	11.60
Jun 23	15.70	12.20
Jun 24	16.10	12.00
Jun 25	19.00	12.30
Jun 26	17.50	13.00
Jun 27	18.70	13.00
Jun 28	16.00	13.00
Jun 29	15.80	12.40
Jun 30	16.80	10.90
Jul 01	14.20	13.20
Jul 02	13.60	12.90
Jul 03	14.50	13.00
Jul 04	14.90	12.20
Jul 05	16.70	10.90
Jul 06	17.10	13.20
Jul 07	15.90	13.00
Jul 08	16.40	12.90
Jul 09	16.70	12.50
Jul 10	16.50	12.60
Jul 11	16.20	12.50
Jul 12	16.30	13.10
Jul 13	16.00	13.40
Jul 14	15.40	13.90
Jul 15	16.20	13.60
Jul 16	16.00	13.30
Jul 17	15.50	13.60
Jul 18	18.40	14.20
Jul 19	19.70	13.40
Jul 20	20.30	15.10
Jul 21	18.40	14.60
Jul 22	19.10	13.90
Jul 23	18.40	15.40
Jul 24	16.60	15.20
Jul 25	17.80	14.90
Jul 26	18.00	13.90
Jul 27	17.30	14.60
Jul 28	17.20	14.50
Jul 29	18.20	15.20
Jul 30	18.00	13.60
Jul 31	18.20	14.30
Aug 01	18.70	13.50
Aug 02	19.20	15.80
Aug 03	19.40	16.40
Aug 04	19.20	16.70
Aug 05	19.40	15.70
Aug 06	19.60	14.30
Aug 07	17.10	14.70
Aug 08	18.00	14.30
Aug 09	19.00	14.00
Aug 10	19.90	14.00
Aug 11	19.10	14.50
Aug 12	19.10	15.70
Aug 13	19.70	15.10
Aug 14	19.10	15.10
Aug 15	19.20	15.40
Aug 16	18.90	16.00
Aug 17	19.10	14.90
Aug 18	18.50	16.20
Aug 19	18.10	14.80
Aug 20	18.20	15.30
Aug 21	17.70	14.70
Aug 22	16.30	15.00
Aug 23	17.50	13.70
Aug 24	17.00	15.10
Aug 25	17.10	15.00
Aug 26	17.50	15.10
Aug 27	17.70	14.80
Aug 28	16.80	16.10
Aug 29	17.80	15.30
Aug 30	18.00	15.70
Aug 31	16.70	16.00
Sep 01	15.80	14.40
Sep 02	15.30	14.10
Sep 03	14.60	14.10
Sep 04	15.50	13.80
Sep 05	15.30	13.20
Sep 06	15.20	13.70
Sep 07	15.10	14.50
Sep 08	15.10	14.40
Sep 09	14.40	13.20
Sep 10	13.70	13.00
Sep 11	13.80	13.00
Sep 12	14.00	13.20
Sep 13	13.80	13.20
Sep 14	14.40	13.60
Sep 15	14.70	13.90
Sep 16	15.20	13.90
Sep 17	15.10	14.30
Sep 18	15.50	15.10
Sep 19	15.90	14.90
Sep 20	16.40	15.00
Sep 21	16.50	14.90
Sep 22	16.20	14.40
Sep 23	15.40	14.20
Sep 24	15.10	14.00
Sep 25	14.90	14.10
Sep 26	14.70	13.50
Sep 27	14.50	12.90
Sep 28	14.30	12.90
Sep 29	14.50	13.90
Sep 30	14.90	14.30
Oct 01	15.20	14.00
Oct 02	13.80	12.60
Oct 03	12.80	11.70
Oct 04	12.50	11.00
Oct 05	11.60	10.60
Oct 06	11.80	11.00
Oct 07	11.80	10.30
Oct 08	11.50	10.00
Oct 09	11.30	10.30
Oct 10	11.70	10.60
Oct 11	11.00	9.70
Oct 12	10.40	9.10
Oct 13	9.50	9.10
Oct 14	10.30	9.10
Oct 15	9.90	8.90
Oct 16	9.40	8.40
Oct 17	9.50	8.90
Oct 18	9.10	8.60
Oct 19	9.60	8.90
Oct 20	10.30	9.40
Oct 21	10.30	9.70
Oct 22	9.70	9.00
Oct 23	9.90	9.10
Oct 24	9.50	8.90
Oct 25	9.80	8.70
Oct 26	10.30	9.90

Appendix D, Table 3. Daily maximum and minimum water temperatures in **Siwash Creek** between June 15 - October 26, 1994.

Date	Maximum	Minimum
Jun 15	11.50	11.30
Jun 16	12.70	10.60
Jun 17	13.10	10.90
Jun 18	12.50	11.10
Jun 19	13.50	10.20
Jun 20	14.10	10.60
Jun 21	13.40	11.80
Jun 22	14.50	11.60
Jun 23	13.50	12.10
Jun 24	13.40	12.00
Jun 25	14.80	12.20
Jun 26	14.10	12.70
Jun 27	14.60	12.60
Jun 28	13.60	12.60
Jun 29	13.70	12.50
Jun 30	13.50	11.90
Jul 01	13.00	12.40
Jul 02	13.30	12.10
Jul 03	13.60	12.20
Jul 04	13.00	12.00
Jul 05	14.80	11.20
Jul 06	14.90	12.40
Jul 07	14.00	12.70
Jul 08	15.20	12.50
Jul 09	15.40	12.40
Jul 10	15.20	12.20
Jul 11	15.30	12.30
Jul 12	15.50	12.90
Jul 13	14.80	13.30
Jul 14	14.20	13.30
Jul 15	14.10	12.90
Jul 16	14.30	12.80
Jul 17	13.90	13.00
Jul 18	16.10	13.20
Jul 19	17.10	13.30
Jul 20	17.40	14.30
Jul 21	16.80	14.30
Jul 22	16.70	14.00
Jul 23	16.30	14.60
Jul 24	15.70	14.60
Jul 25	16.10	14.10
Jul 26	16.60	13.80
Jul 27	15.80	14.60
Jul 28	15.20	14.00
Jul 29	16.20	14.40
Jul 30	16.30	13.60
Jul 31	16.70	14.20
Aug 01	16.70	13.70
Aug 02	17.40	15.10

Date	Maximum	Minimum
Aug 03	17.40	15.70
Aug 04	17.10	15.80
Aug 05	17.30	15.10
Aug 06	16.80	14.00
Aug 07	15.70	14.50
Aug 08	15.50	13.70
Aug 09	16.00	13.70
Aug 10	16.50	13.70
Aug 11	16.50	14.00
Aug 12	16.40	14.90
Aug 13	17.00	14.60
Aug 14	16.40	14.40
Aug 15	16.70	14.30
Aug 16	16.60	15.10
Aug 17	16.80	14.20
Aug 18	17.20	15.30
Aug 19	16.50	14.90
Aug 20	16.40	14.80
Aug 21	16.10	14.40
Aug 22	15.30	14.50
Aug 23	15.70	13.30
Aug 24	15.70	13.70
Aug 25	15.70	13.70
Aug 26	15.90	13.70
Aug 27	15.90	13.00
Aug 28	15.50	14.40
Aug 29	15.90	13.70
Aug 30	16.00	13.80
Aug 31	15.50	14.60
Sep 01	14.90	13.20
Sep 02	14.10	12.60
Sep 03	13.70	13.10
Sep 04	14.30	12.50
Sep 05	14.20	11.80
Sep 06	14.60	12.70
Sep 07	14.50	13.60
Sep 08	14.10	13.20
Sep 09	13.50	12.80
Sep 10	13.70	12.40
Sep 11	13.90	12.20
Sep 12	13.50	12.10
Sep 13	13.30	12.40
Sep 14	13.80	13.00
Sep 15	14.40	13.50
Sep 16	15.20	13.30
Sep 17	14.90	13.50
Sep 18	14.80	14.00
Sep 19	15.10	13.70
Sep 20	15.20	14.10

Date	Maximum	Minimum
Sep 21	15.20	13.50
Sep 22	14.70	13.00
Sep 23	14.20	12.90
Sep 24	14.10	13.00
Sep 25	14.20	13.30
Sep 26	13.60	11.90
Sep 27	13.70	11.90
Sep 28	13.30	11.90
Sep 29	13.80	12.90
Sep 30	14.30	13.40
Oct 01	14.10	12.80
Oct 02	12.60	11.30
Oct 03	11.60	9.80
Oct 04	11.30	9.80
Oct 05	10.80	9.60
Oct 06	11.40	10.50
Oct 07	11.00	9.50
Oct 08	10.90	9.30
Oct 09	11.10	9.80
Oct 10	11.00	10.00
Oct 11	10.20	8.90
Oct 12	9.70	8.20
Oct 13	9.20	8.30
Oct 14	9.70	8.80
Oct 15	9.40	8.30
Oct 16	9.00	7.70
Oct 17	9.40	8.50
Oct 18	9.10	8.20
Oct 19	9.60	8.50
Oct 20	10.00	9.40
Oct 21	10.00	9.30
Oct 22	9.20	8.40
Oct 23	9.80	9.00
Oct 24	9.20	8.10
Oct 25	10.00	8.80
Oct 26	10.20	9.90

Appendix D, Table 4. Daily maximum and minimum water temperatures in **South Creek** between June 15 - October 26, 1994.

Date	Maximum	Minimum
Jun 15	12.70	12.10
Jun 16	13.40	10.90
Jun 17	13.80	11.30
Jun 18	13.20	11.80
Jun 19	13.90	10.60
Jun 20	14.70	11.40
Jun 21	14.20	12.80
Jun 22	15.10	12.50
Jun 23	14.30	13.20
Jun 24	14.00	12.80
Jun 25	15.00	13.00
Jun 26	15.00	13.60
Jun 27	15.50	13.60
Jun 28	14.90	13.60
Jun 29	14.30	13.40
Jun 30	14.10	12.60
Jul 01	13.80	12.60
Jul 02	13.70	12.30
Jul 03	13.90	12.70
Jul 04	13.50	12.50
Jul 05	15.00	11.90
Jul 06	15.50	13.50
Jul 07	15.10	13.70
Jul 08	15.40	13.10
Jul 09	15.90	13.00
Jul 10	16.10	13.30
Jul 11	15.80	13.20
Jul 12	16.20	14.00
Jul 13	15.90	14.40
Jul 14	15.50	14.40
Jul 15	14.80	13.80
Jul 16	15.00	13.70
Jul 17	14.90	14.00
Jul 18	16.40	14.10
Jul 19	17.40	14.70
Jul 20	18.00	15.90
Jul 21	17.70	16.30
Jul 22	17.30	15.90
Jul 23	17.00	16.20
Jul 24	16.70	15.70
Jul 25	16.80	15.20
Jul 26	17.10	15.70
Jul 27	16.60	15.90
Jul 28	16.00	15.40
Jul 29	16.70	15.80
Jul 30	16.40	15.20
Jul 31	17.00	15.40
Aug 01	17.20	15.30
Aug 02	17.80	16.30

Date	Maximum	Minimum
Aug 03	18.40	17.30
Aug 04	18.30	17.50
Aug 05	18.20	17.10
Aug 06	17.50	16.00
Aug 07	16.60	15.50
Aug 08	15.80	14.90
Aug 09	16.20	14.90
Aug 10	16.80	14.90
Aug 11	17.00	15.20
Aug 12	17.20	16.10
Aug 13	17.60	16.00
Aug 14	17.20	16.00
Aug 15	17.30	15.70
Aug 16	17.20	16.20
Aug 17	17.10	15.50
Aug 18	17.80	16.40
Aug 19	17.40	16.40
Aug 20	17.20	16.20
Aug 21	16.70	15.90
Aug 22	16.20	15.40
Aug 23	16.00	14.50
Aug 24	16.10	14.80
Aug 25	15.90	14.60
Aug 26	16.20	14.60
Aug 27	16.20	14.20
Aug 28	16.20	15.30
Aug 29	16.40	14.90
Aug 30	16.40	14.90
Aug 31	16.10	15.40
Sep 01	15.30	14.10
Sep 02	14.30	13.60
Sep 03	14.10	13.80
Sep 04	14.10	13.00
Sep 05	14.10	12.50
Sep 06	14.70	13.20
Sep 07	14.90	14.20
Sep 08	14.70	13.60
Sep 09	14.00	13.20
Sep 10	14.00	12.60
Sep 11	14.00	12.70
Sep 12	13.90	13.10
Sep 13	13.60	13.30
Sep 14	14.00	13.40
Sep 15	14.70	13.80
Sep 16	15.30	13.70
Sep 17	15.20	14.00
Sep 18	15.20	14.70
Sep 19	15.20	14.60
Sep 20	15.70	15.10

Date	Maximum	Minimum
Sep 21	15.30	14.80
Sep 22	14.90	14.30
Sep 23	14.70	14.00
Sep 24	14.70	14.10
Sep 25	14.50	14.00
Sep 26	13.90	13.10
Sep 27	13.70	12.70
Sep 28	13.30	12.70
Sep 29	13.90	13.20
Sep 30	14.50	13.90
Oct 01	14.50	13.50
Oct 02	13.40	11.90
Oct 03	11.80	11.20
Oct 04	11.40	10.30
Oct 05	10.60	9.90
Oct 06	11.30	10.40
Oct 07	10.90	10.10
Oct 08	10.50	9.40
Oct 09	10.80	9.80
Oct 10	10.90	10.20
Oct 11	10.20	9.40
Oct 12	9.40	8.70
Oct 13	9.00	8.50
Oct 14	9.40	8.90
Oct 15	9.20	8.60
Oct 16	8.70	8.00
Oct 17	9.10	8.20
Oct 18	8.80	8.50
Oct 19	9.20	8.50
Oct 20	10.30	9.20
Oct 21	10.20	9.60
Oct 22	9.50	8.50
Oct 23	10.00	9.00
Oct 24	9.50	8.40
Oct 25	10.30	9.10
Oct 26	10.50	10.10

Appendix D, Table 5. Daily maximum and minimum water temperatures in **Umbrella Creek** between June 16 - October 26, 1994.

Date	Maximum	Minimum
Jun 16	13.60	11.30
Jun 17	14.40	11.30
Jun 18	13.50	12.00
Jun 19	14.80	10.90
Jun 20	15.90	11.80
Jun 21	14.90	13.30
Jun 22	16.20	13.20
Jun 23	15.70	13.70
Jun 24	15.10	13.70
Jun 25	15.70	13.50
Jun 26	15.20	13.80
Jun 27	15.40	13.80
Jun 28	15.10	14.10
Jun 29	14.60	13.90
Jun 30	14.50	13.00
Jul 01	14.40	12.40
Jul 02	13.50	12.00
Jul 03	13.70	12.50
Jul 04	13.70	12.40
Jul 05	15.30	11.70
Jul 06	16.00	13.50
Jul 07	15.50	13.80
Jul 08	15.80	13.40
Jul 09	16.20	13.80
Jul 10	16.30	14.10
Jul 11	16.10	14.30
Jul 12	16.50	14.80
Jul 13	16.10	15.10
Jul 14	15.40	15.00
Jul 15	15.70	14.40
Jul 16	15.30	14.70
Jul 17	15.10	14.80
Jul 18	16.70	14.70
Jul 19	17.50	15.30
Jul 20	18.30	16.60
Jul 21	18.20	16.40
Jul 22	18.00	16.30
Jul 23	17.60	16.70
Jul 24	17.00	16.20
Jul 25	17.00	15.90
Jul 26	17.60	15.40
Jul 27	16.80	16.00
Jul 28	16.80	15.90
Jul 29	17.30	16.10
Jul 30	17.20	15.50
Jul 31	17.50	15.70
Aug 01	17.50	15.40
Aug 02	18.30	16.50
Aug 03	18.60	17.20

Date	Maximum	Minimum
Aug 04	18.50	17.40
Aug 05	18.70	17.00
Aug 06	17.70	16.20
Aug 07	16.80	16.00
Aug 08	17.20	15.50
Aug 09	17.20	15.40
Aug 10	18.00	15.70
Aug 11	18.10	15.90
Aug 12	18.00	16.40
Aug 13	18.20	16.10
Aug 14	17.40	16.20
Aug 15	18.30	16.10
Aug 16	18.00	16.70
Aug 17	18.40	16.10
Aug 18	19.10	16.80
Aug 19	18.20	16.40
Aug 20	18.00	16.50
Aug 21	17.30	16.10
Aug 22	16.70	16.10
Aug 23	17.10	15.10
Aug 24	16.70	14.90
Aug 25	16.70	14.70
Aug 26	17.10	15.00
Aug 27	17.00	14.60
Aug 28	17.00	16.00
Aug 29	17.70	15.40
Aug 30	17.50	15.40
Aug 31	16.60	15.40
Sep 01	16.30	14.20
Sep 02	15.40	13.80
Sep 03	14.70	14.10
Sep 04	15.50	14.00
Sep 05	15.20	13.20
Sep 06	15.70	13.60
Sep 07	15.30	14.60
Sep 08	15.10	14.60
Sep 09	14.80	13.20
Sep 10	14.30	12.80
Sep 11	14.40	12.80
Sep 12	14.10	12.70
Sep 13	13.90	13.00
Sep 14	13.80	13.00
Sep 15	14.30	13.40
Sep 16	15.50	13.40
Sep 17	15.40	13.90
Sep 18	15.30	14.60
Sep 19	15.70	14.20
Sep 20	15.90	14.70
Sep 21	16.00	14.50

Date	Maximum	Minimum
Sep 22	15.90	14.00
Sep 23	15.40	14.20
Sep 24	14.70	14.10
Sep 25	14.70	14.20
Sep 26	14.20	13.10
Sep 27	14.00	12.90
Sep 28	14.00	13.20
Sep 29	14.60	13.90
Sep 30	14.90	14.40
Oct 01	14.70	13.80
Oct 02	13.60	11.90
Oct 03	12.40	11.40
Oct 04	12.50	11.20
Oct 05	11.50	10.80
Oct 06	12.20	11.30
Oct 07	12.10	10.70
Oct 08	11.60	10.50
Oct 09	11.50	10.80
Oct 10	12.00	10.80
Oct 11	11.10	9.90
Oct 12	10.50	9.50
Oct 13	9.40	9.10
Oct 14	9.90	9.10
Oct 15	9.60	8.60
Oct 16	9.10	8.30
Oct 17	9.70	8.70
Oct 18	9.40	8.90
Oct 19	9.70	9.00
Oct 20	10.30	9.70
Oct 21	10.20	9.30
Oct 22	9.40	8.10
Oct 23	10.10	8.90
Oct 24	9.60	8.40
Oct 25	10.30	8.90
Oct 26	10.50	10.20

Appendix D, Table 6. Daily maximum and minimum water temperatures in the **Ozette River** between June 16 - October 26, 1994.

Date	Maximum	Minimum
Jun 15	19.00	13.80
Jun 16	16.70	15.40
Jun 17	15.80	14.40
Jun 18	16.40	14.10
Jun 19	16.50	14.00
Jun 20	17.40	13.80
Jun 21	17.10	15.30
Jun 22	19.00	16.80
Jun 23	19.20	18.10
Jun 24	18.50	17.60
Jun 25	17.80	17.20
Jun 26	17.70	16.80
Jun 27	18.00	15.80
Jun 28	17.60	15.50
Jun 29	17.30	16.50
Jun 30	18.20	16.30
Jul 01	18.00	17.30
Jul 02	17.80	17.20
Jul 03	17.50	17.10
Jul 04	17.60	17.00
Jul 05	18.70	16.70
Jul 06	19.10	17.20
Jul 07	17.80	16.40
Jul 08	18.00	16.40
Jul 09	19.80	16.80
Jul 10	20.30	18.40
Jul 11	19.90	18.40
Jul 12	20.60	18.60
Jul 13	20.50	19.30
Jul 14	19.80	19.20
Jul 15	20.10	19.00
Jul 16	19.60	18.90
Jul 17	19.30	18.60
Jul 18	19.80	18.40
Jul 19	22.60	18.10
Jul 20	20.90	18.70
Jul 21	21.30	19.30
Jul 22	22.60	19.80
Jul 23	22.10	20.30
Jul 24	21.70	21.00
Jul 25	22.10	20.70
Jul 26	21.60	19.60
Jul 27	20.90	19.20
Jul 28	20.90	19.90
Jul 29	21.00	20.10
Jul 30	20.70	19.40
Jul 31	21.00	19.40
Aug 01	22.80	19.10
Aug 02	22.10	20.40
Aug 03	22.80	20.10
Aug 04	23.30	21.60
Aug 05	23.70	21.70

Date	Maximum	Minimum
Aug 06	22.30	21.20
Aug 07	21.80	20.50
Aug 08	22.60	21.00
Aug 09	23.00	21.00
Aug 10	23.10	20.60
Aug 11	21.80	20.40
Aug 12	21.50	20.30
Aug 13	21.70	20.10
Aug 14	22.20	20.30
Aug 15	23.20	20.70
Aug 16	23.50	21.60
Aug 17	23.10	21.20
Aug 18	23.20	20.70
Aug 19	23.50	21.70
Aug 20	23.30	21.70
Aug 21	22.80	21.60
Aug 22	22.00	21.50
Aug 23	22.80	21.00
Aug 24	22.50	20.50
Aug 25	22.80	20.40
Aug 26	22.80	20.50
Aug 27	23.00	20.00
Aug 28	22.10	21.10
Aug 29	22.70	20.90
Aug 30	22.00	20.40
Aug 31	21.10	20.10
Sep 01	21.10	19.60
Sep 02	20.60	18.70
Sep 03	20.00	19.00
Sep 04	21.30	19.20
Sep 05	21.20	18.60
Sep 06	21.30	19.00
Sep 07	20.40	19.10
Sep 08	20.30	19.20
Sep 09	19.70	13.70
Sep 10	20.90	18.60
Sep 11	20.10	18.60
Sep 12	20.10	18.30
Sep 13	18.70	18.30
Sep 14	19.20	18.40
Sep 15	19.80	18.60
Sep 16	21.10	18.60
Sep 17	20.10	18.60
Sep 18	18.70	18.20
Sep 19	19.10	18.00
Sep 20	19.10	18.00
Sep 21	20.30	17.80
Sep 22	20.40	18.70
Sep 23	19.40	18.50
Sep 24	20.00	18.30
Sep 25	19.10	18.50
Sep 26	19.90	18.10

Date	Maximum	Minimum
Sep 27	19.40	18.00
Sep 28	19.60	17.80
Sep 29	19.20	18.70
Sep 30	19.00	18.40
Oct 01	19.40	18.20
Oct 02	19.40	17.60
Oct 03	19.10	17.50
Oct 04	18.90	17.40
Oct 05	17.70	17.10
Oct 06	17.80	17.30
Oct 07	18.70	16.60
Oct 08	17.80	16.50
Oct 09	17.50	16.40
Oct 10	17.70	16.50
Oct 11	17.60	16.10
Oct 12	17.50	16.10
Oct 13	16.20	15.30
Oct 14	16.60	15.70
Oct 15	16.80	15.10
Oct 16	16.70	15.30
Oct 17	16.20	15.40
Oct 18	15.50	15.00
Oct 19	15.50	14.80
Oct 20	15.30	14.60
Oct 21	16.10	14.50
Oct 22	14.90	13.90
Oct 23	15.40	14.40
Oct 24	15.30	14.10
Oct 25	14.50	14.00
Oct 26	11.50	11.30